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Welcome

Exactly 15 years ago this month, Space Shuttle Columbia was making its return flight to Earth. On board were seven astronauts: mission specialists Laurel Clark, David Brown and Kalpana Chawla, payload specialist Ilan Ramon, payload commander Michael Anderson, pilot William McCool and commander Rick Husband. Sadly, the crew members wouldn't be meeting their friends or family after their 16-day mission, on which they carried out an impressive multitude of scientific experiments. Columbia disintegrated as it plunged through our planet's atmosphere, where it was heated to enormously high temperatures, killing everyone inside its cockpit.

It was a tragedy that shook NASA, forcing the space agency to cease operations of the Space Shuttle program for over two years. The culprit responsible for Columbia's in-flight break up was a chunk of foam that had broken off the space vehicle's external tank. During liftoff, the flyaway piece struck the left wing, causing irreparable damage. Flight control reasoned that it was best that the crew didn't know about their impending doom, and so they waited until they lost contact with the astronauts. What did NASA learn from the disaster? A lot. The bravery of Columbia's crew has assisted in our future of space exploration in more ways than one – turn to page 60 to find out how.

Gemma Lavender
Editor

@NASA

Our contributors include...

Colin Stuart
Astronomer & author
It turns out that probing into gravitational waves implies that there will be a 'bang' at the end of the universe. Colin chats to Sir Roger Penrose about the latest findings.

Ian Evenden
Science & technology writer
Seven astronauts perished on board Space Shuttle Columbia 15 years ago this month. Ian uncovers what NASA learned from the tragedy.

Benjamin Skuse
Mathematician & science writer
Believe it or not, space changes how you think. Benjamin meets the researchers probing astronaut brains, with some surprising results.

Nick Spall
Space and science writer
Nick headed over to ESA's European Astronaut Centre (EAC) in Cologne to chat to Tim Peake about his next big mission into space.

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What happened, what NASA learned
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HUSBAND MCCOOL
STS 107

Exclusive from ESA

"I could one day take a seat in one of the US vehicles rather than in [one of the seats] of the Soyuz"

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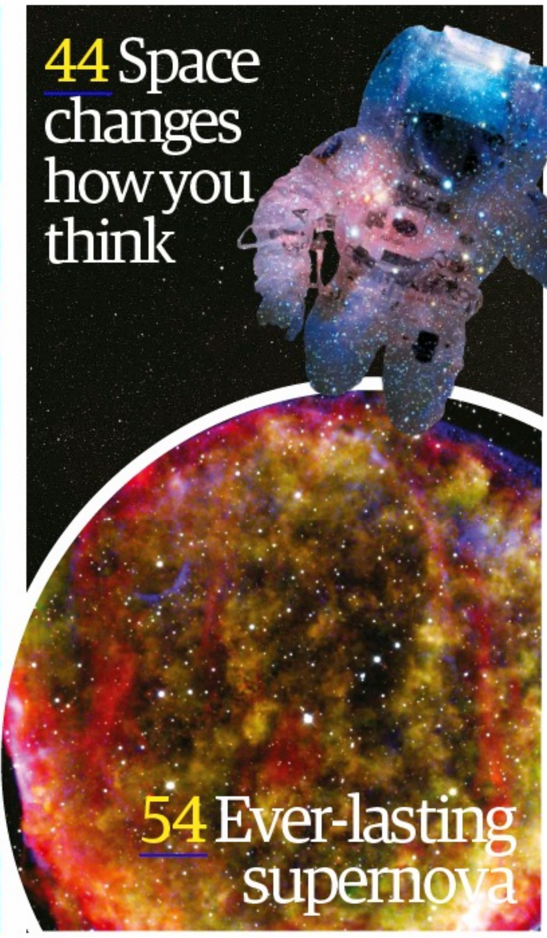
UK ESA astronaut



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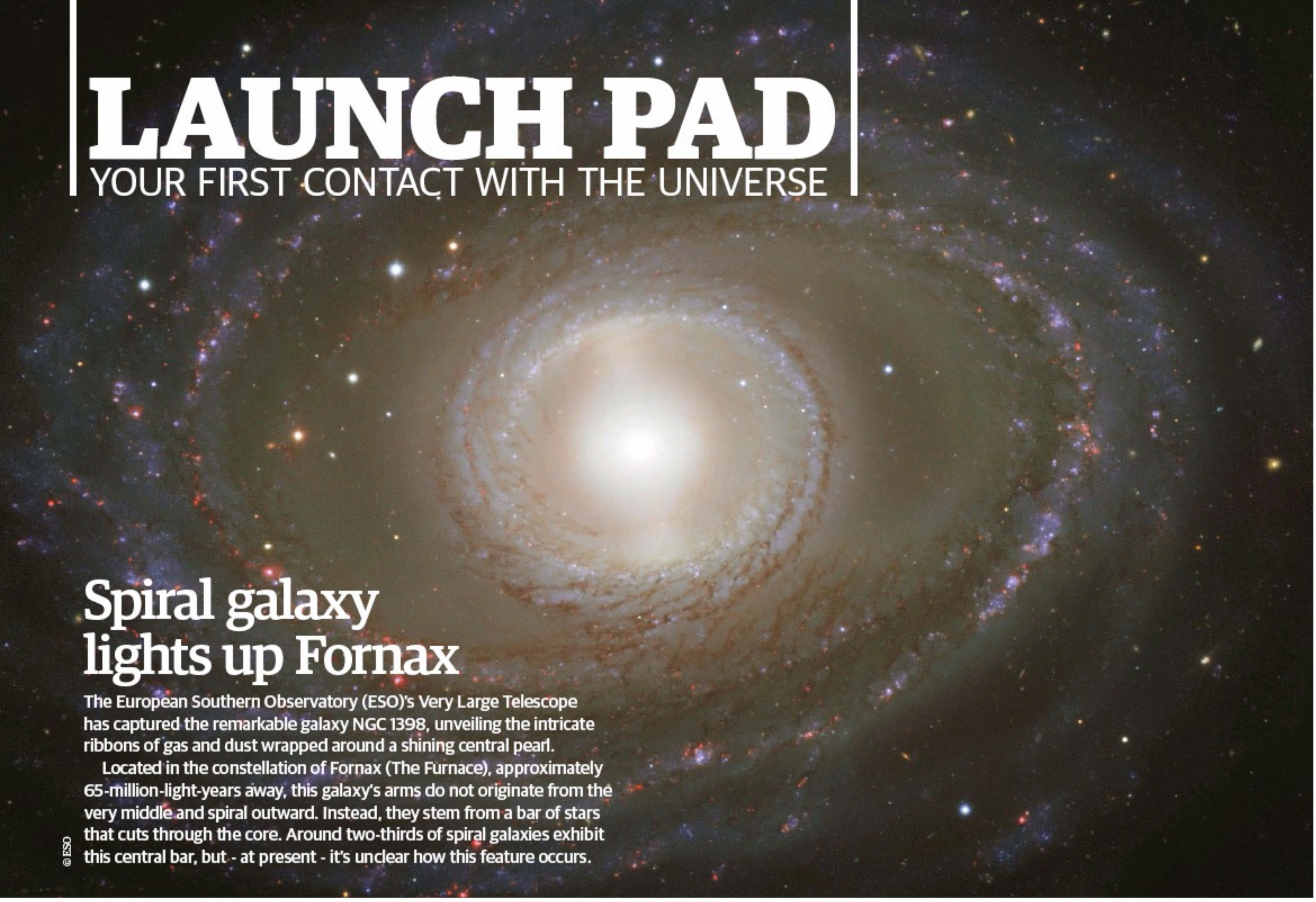


Spiral galaxy lights up Fornax

The European Southern Observatory (ESO)'s Very Large Telescope has captured the remarkable galaxy NGC 1398, unveiling the intricate ribbons of gas and dust wrapped around a shining central pearl.

Located in the constellation of Fornax (The Furnace), approximately 65-million-light-years away, this galaxy's arms do not originate from the very middle and spiral outward. Instead, they stem from a bar of stars that cuts through the core. Around two-thirds of spiral galaxies exhibit this central bar, but - at present - it's unclear how this feature occurs.

© ESO

Star Wars on the International Space Station

In a space station far, far away, there was a happy group of astronauts who sat down to watch the latest instalment of the *Star Wars* saga.

Soon after the premiere of *Star Wars: The Last Jedi*, the astronauts on board the International Space Station were able to get their own viewing of it at around 400 kilometres (250 miles) above the ground. During the time it took them to watch this movie, they had completed over one and a half orbits of the Earth.

© NASA

Launching more Galileo satellites

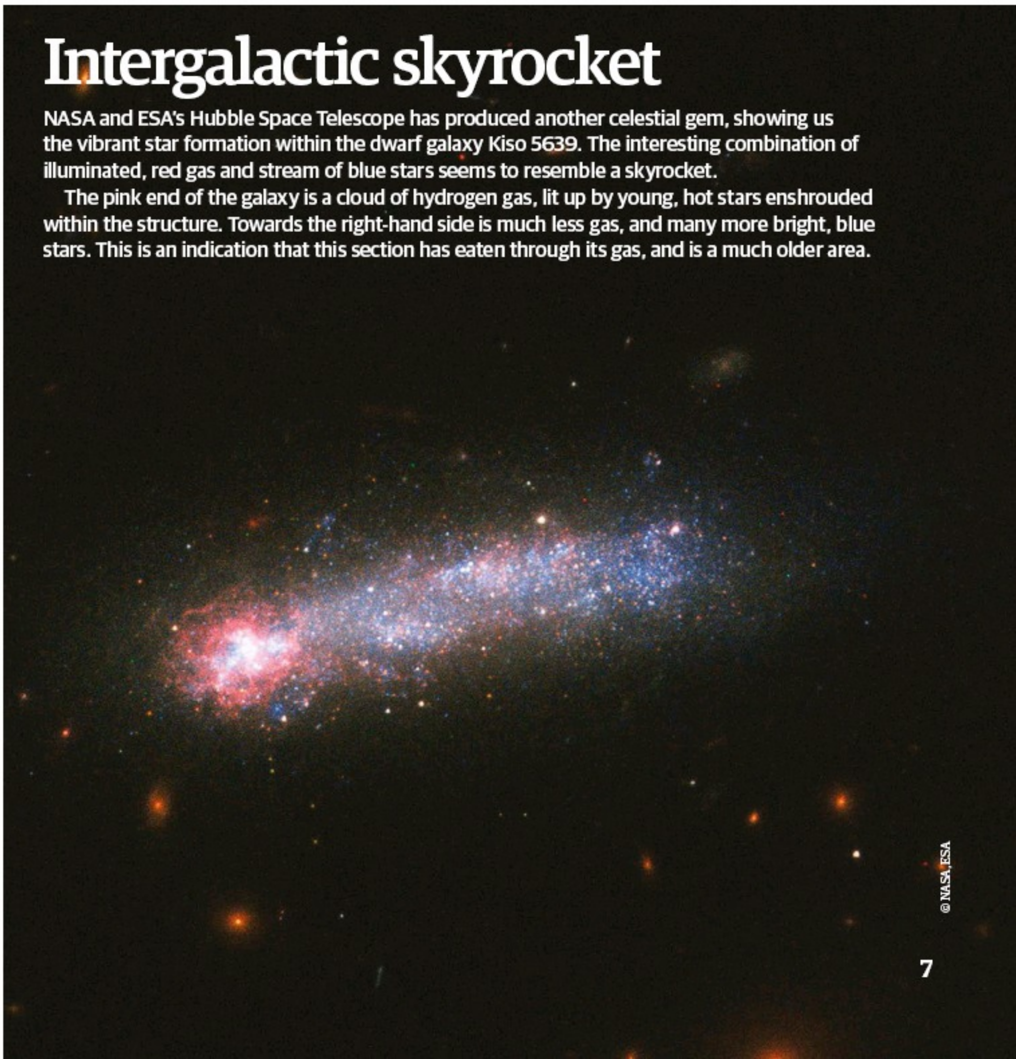
ESA's Galileo constellation of satellites continues to progress with another launch from Europe's Spaceport in Kourou, French Guiana. Four more craft were sent up into space on board an Ariane 5 rocket, transporting Galileo satellites 19 to 22. These satellites were sent to an astonishing orbital altitude of 22,922 kilometres (14,243 miles), where the finished project will consist of 24 operational satellites and six spares already in orbit. Together they will provide Europe with its own global navigation satellite system.

© ESA-Manuel Pedoussaut

Intergalactic skyrocket

NASA and ESA's Hubble Space Telescope has produced another celestial gem, showing us the vibrant star formation within the dwarf galaxy Kiso 5639. The interesting combination of illuminated, red gas and stream of blue stars seems to resemble a skyrocket.

The pink end of the galaxy is a cloud of hydrogen gas, lit up by young, hot stars enshrouded within the structure. Towards the right-hand side is much less gas, and many more bright, blue stars. This is an indication that this section has eaten through its gas, and is a much older area.



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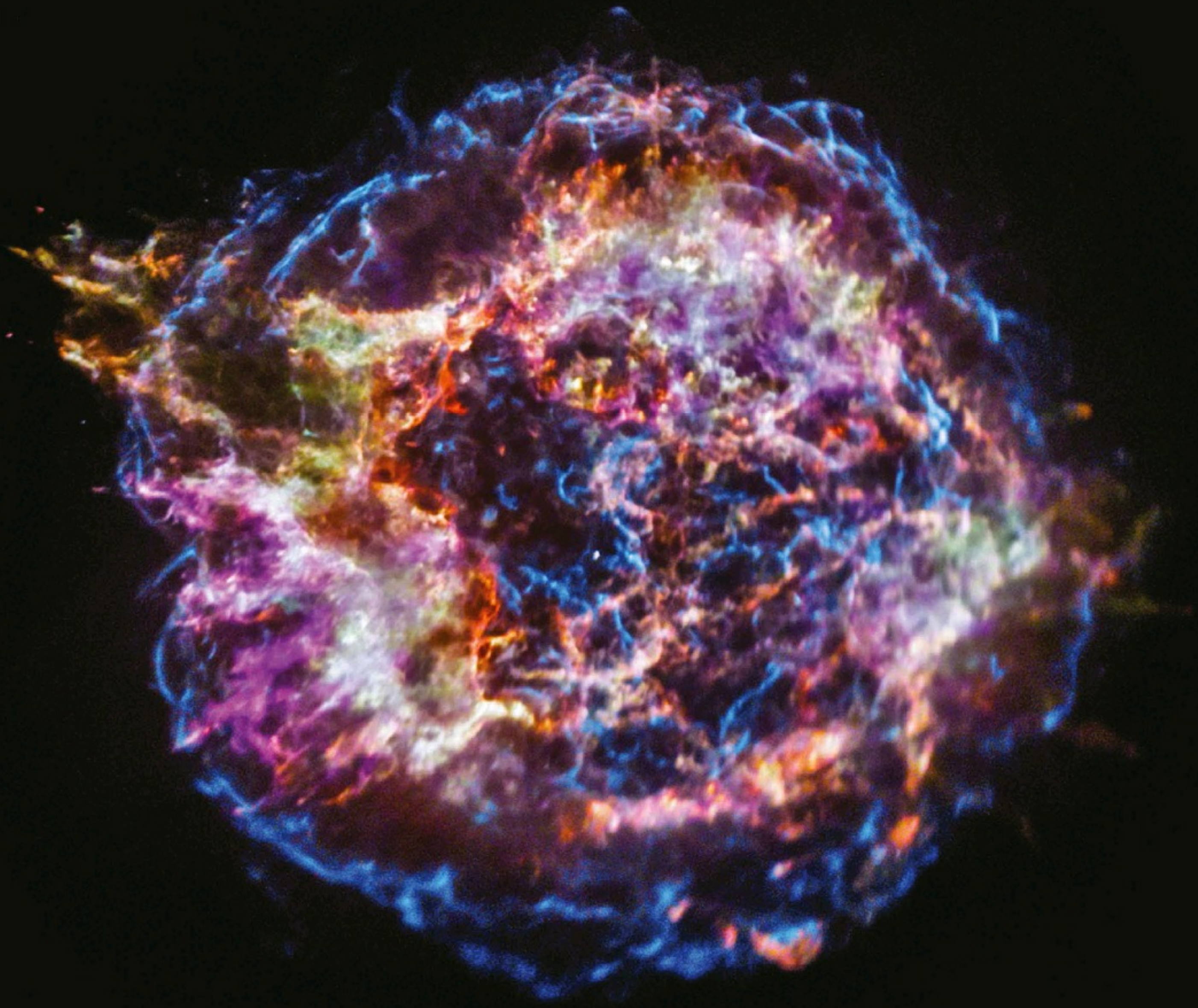

Mapping the husks of a dead star

What happens when a star comes to the end of its life? It explodes in a spectacular fashion, in what is known as a supernova. The remnants of this eruption are cast into the cosmos, where they are recycled into more stars, planets and other celestial items that reside in outer space.

NASA's Chandra X-ray Observatory has managed to map the locations of different elements within the supernova explosion commonly known as Cassiopeia A. In this X-ray image, silicon is shown in red, sulphur in yellow, calcium in green and iron in an electric shade of purple.

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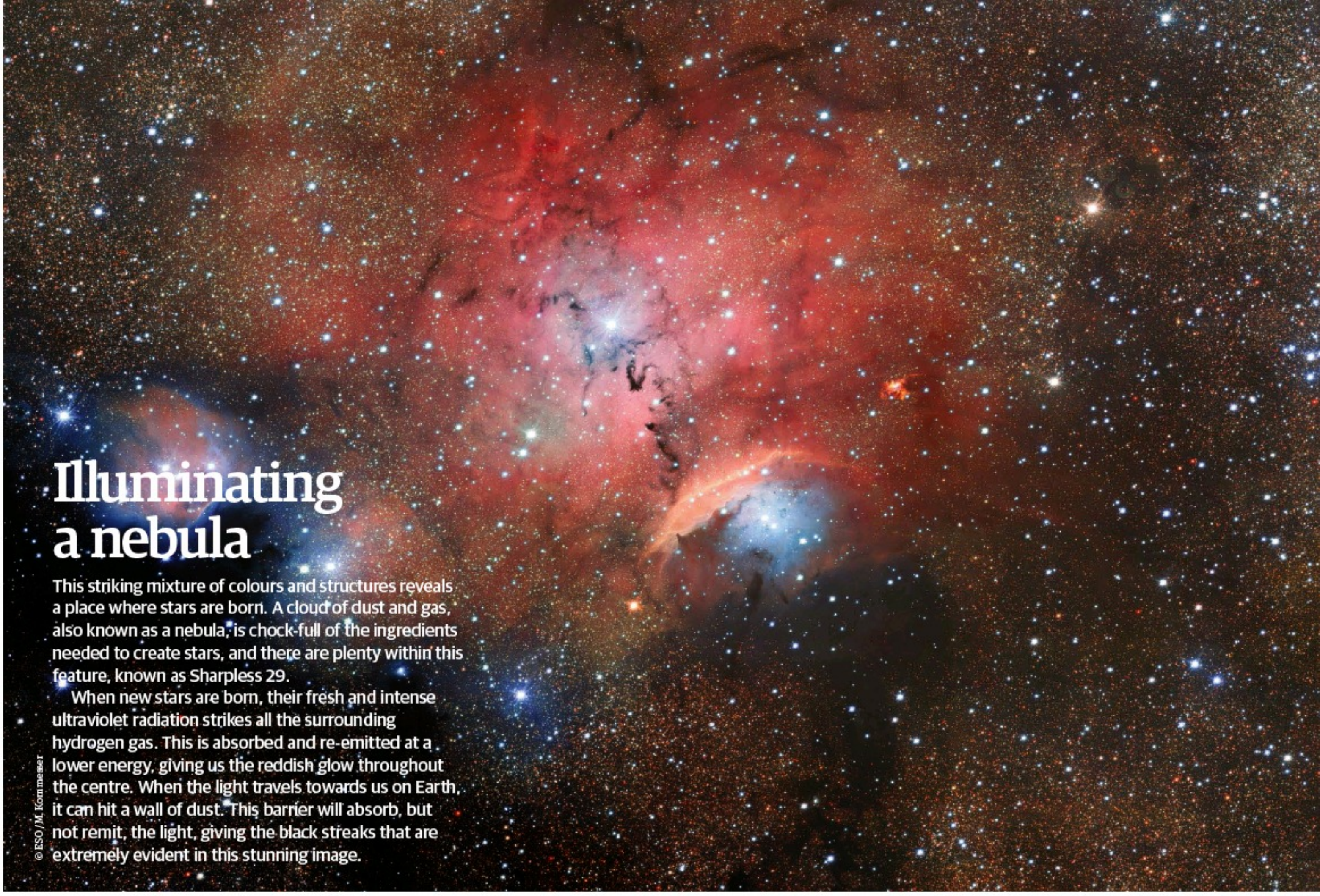

Illuminating a nebula

This striking mixture of colours and structures reveals a place where stars are born. A cloud of dust and gas, also known as a nebula, is chock-full of the ingredients needed to create stars, and there are plenty within this feature, known as Sharpless 29.

When new stars are born, their fresh and intense ultraviolet radiation strikes all the surrounding hydrogen gas. This is absorbed and re-emitted at a lower energy, giving us the reddish glow throughout the centre. When the light travels towards us on Earth, it can hit a wall of dust. This barrier will absorb, but not remit, the light, giving the black streaks that are extremely evident in this stunning image.

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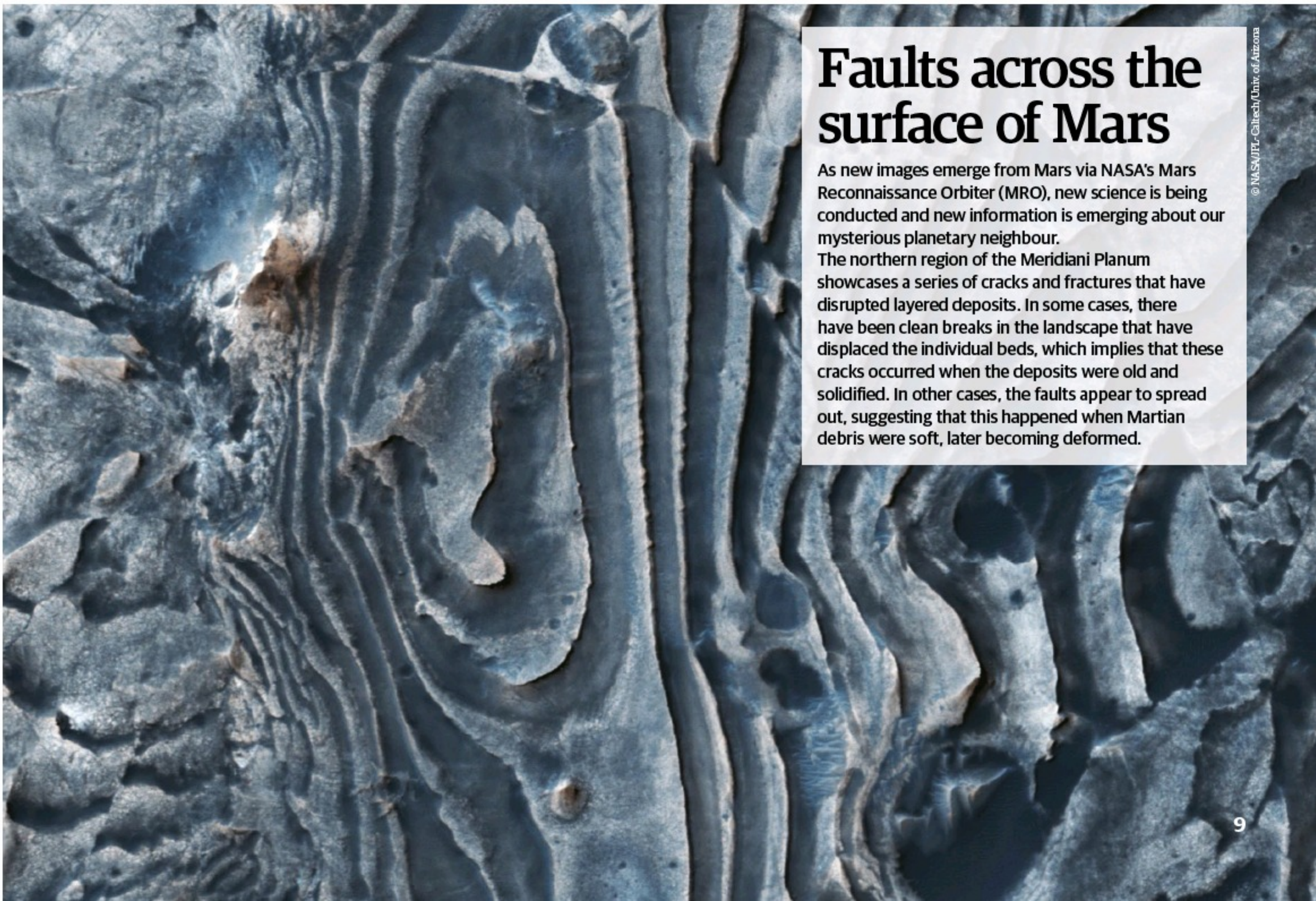

Faults across the surface of Mars

As new images emerge from Mars via NASA's Mars Reconnaissance Orbiter (MRO), new science is being conducted and new information is emerging about our mysterious planetary neighbour.

The northern region of the Meridiani Planum showcases a series of cracks and fractures that have disrupted layered deposits. In some cases, there have been clean breaks in the landscape that have displaced the individual beds, which implies that these cracks occurred when the deposits were old and solidified. In other cases, the faults appear to spread out, suggesting that this happened when Martian debris were soft, later becoming deformed.

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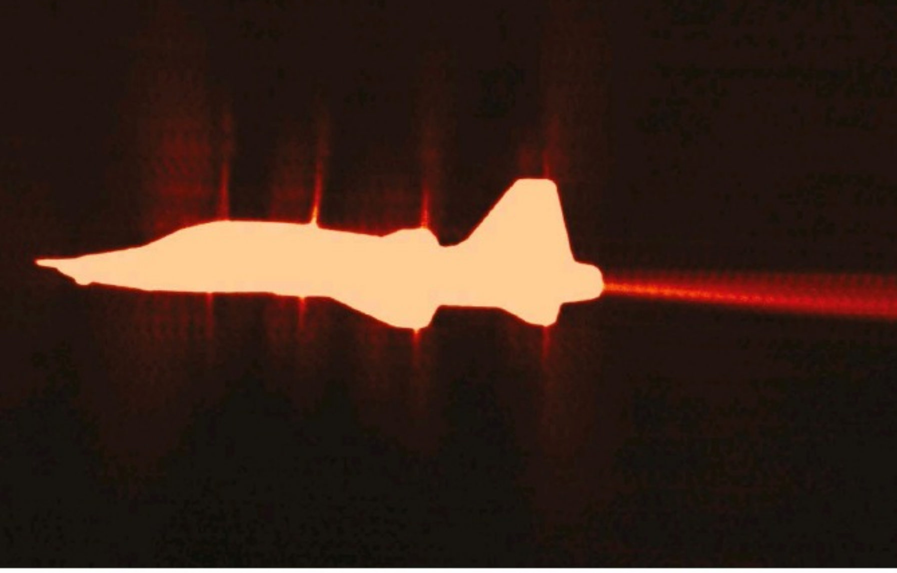
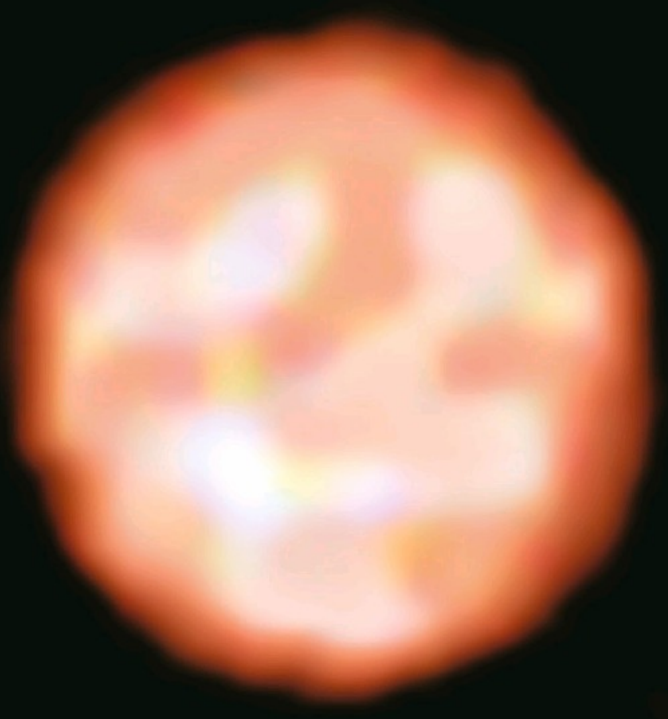
Catching the X-Plane's sonic boom



Seeing a supersonic plane is one thing, but imaging it is something much harder. This is the case with NASA's new X-Plane that was captured in a transonic state, meaning it was captured moving from subsonic speeds to supersonic.

This was a test flight at NASA's Armstrong Flight Research Centre in California, United States, and has helped the agency in their attempt to visually capture the shock waves emanating from the aircraft. Shock waves can be seen above and below the aircraft and, when they hit the ground, they can be heard as an almighty atmospheric eruption. By studying these shock waves, researchers hope to make sonic booms quieter, so they can get the aircraft closer to the ground.

© NASA



Bubbles on a red giant star

The Very Large Telescope turned its sights to the cool, red giant star known as Pi1 Gruis, which could reveal some clues as to what will eventually happen to the Sun later on in its life.

Pi1 Gruis has the same mass of the Sun, but is 350-times larger in size. This is due to the fact that the star is dying, swelling as it approaches its end. The telescope has managed to image its surface with great clarity, showing the massive convective cells that are around a quarter the size of our nearest star.

© ESO

Results of the Great American Eclipse

On the 21 August 2017, a total solar eclipse caused a visually glorious view that was observed keenly by citizens of the United States. Not only was this a wonderful sight, it also provided scientists with a valuable opportunity to study the Sun's corona.

The corona is the high-temperature region surrounding the Sun, which is normally out of view due to the highly-luminous photosphere. When the Moon blocked out this light, the corona became apparent. It wasn't until December 2017 when scientists could get together to discuss initial scientific results gathered from the event.

© NASA

A supermoon visits La Silla Observatory

ESO's La Silla Observatory in the Atacama Desert of Chile is home to many telescopes. Here a supermoon 'resting' atop the Chilean mountains pays it a visit. Due to the slightly elliptical orbit of the Moon around the Earth, our lunar companion reaches its closest position to the Earth – also known as its perigee – every 28 days. When this event coincides with a full Moon, which happens every 29.5 days, a supermoon is born. This event causes the Moon to appear 10 per cent larger in the sky and causes much marvel.

© ESO / L Saviane

Space fever: strange condition astronauts will catch on long missions

Scientists say those on lengthy space flights find it much harder to regulate their body temperature, causing it to rise

An astronaut's body temperature rises during extended zero-gravity missions, a study has shown, potentially affecting the desirability of long-term space flights. Scientists found that the core body temperature of astronauts increases by about one degree Celsius (1.8 degrees Fahrenheit) over a period of ten or so weeks in space.

The findings are being treated with some concern. They come ahead of planned missions to Mars not only by NASA, but private agencies such as SpaceX. The problem appears to be due to the body's difficulty in eliminating excess heat under weightless conditions. While it also happens at rest, the situation is far worse during vital periods of exercise.

> “Even minor increases in core body temperature can impair physical and cognitive performance”

Indeed, the core body temperature can actually exceed 40 degrees Celsius (104 degrees Fahrenheit) during physical exercise in space. What's more troubling is that the core body temperature also rises much faster than when on the ground, with cooling sweat evaporating more slowly. Given the core body temperature of humans should be around 37 degrees Celsius (98.6 degrees Fahrenheit), this issue is potentially life-threatening. Little wonder scientists are referring to the effects as “space fever”.

“Even minor increases in core body temperature can impair physical and cognitive performance,” the researchers wrote in the journal *Scientific Reports* after studying 11 astronauts before, during and after their stays on the International Space Station. Yet the problem is compounded by another finding: that long-term space flights bring on a pro-inflammatory response in astronauts. Again, this affects the core body temperature.

“Both findings have a considerable impact on astronauts' health and well-being during future long-term spaceflights,” the researchers add. “Moreover, our findings pinpoint crucial physiological challenges for spacefaring civilizations, and [they] raise questions about the assumption of a thermoregulatory set point in humans, and our evolutionary ability to adapt to climate changes on Earth.”

Even so, it perhaps won't come as a major surprise to the astronauts themselves. “This is in line with anecdotal evidence from cosmonauts complaining about thermal discomfort,” the researchers say, noting that 80 per cent of the energy used up is converted to heat, causing heat stress when exercising. But, they add: “Given that exercise will be one of the key countermeasures of future long-duration space missions, studies investigating the effects of thermoregulation during spaceflight are critically needed.”

©NASA

Exercising on the ISS can send temperatures skywards of 40°C (104°F)

Humans would need to fly for about seven months if they are to get to Mars. “It is well known that the tight control of CBT is a prerequisite for maintaining physical and mental performance,” says Professor Hanns-Christian Gunga, deputy director of the Institute of Physiology. “Severe CBT deviations can have life-threatening consequences.”

©NASA/ MSFC

NASA creates new logo to mark 60 years

Space agency is celebrating its anniversary with a new commemorative artwork

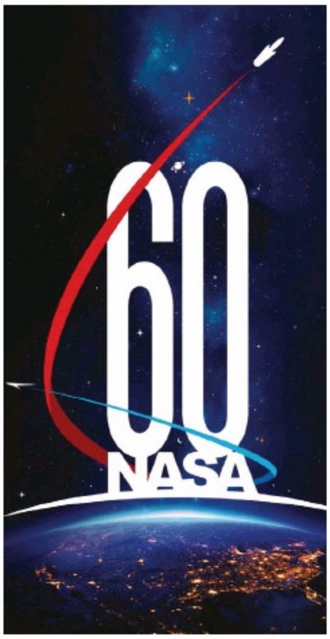
NASA has unveiled a new logo to mark its 60th anniversary as a US government agency. Created by Matthew Skeins, a graphic artist for the National Aeronautics and Space Administration, it is said to depict "how NASA is building on its historic past to soar toward a challenging and inspiring future".

The space agency was established on 29 July 1958 when legislation was signed by President Dwight Eisenhower. It formally began operation on 1 October that year, with just 8,000 employees and an annual budget of $100 million. The first launch, Pioneer 1, followed 11 days later, but it wasn't until 20 July 1969 that it truly made its mark: winning the space race and seeing Neil Armstrong become the first human to set foot on the Moon.

For the latest official logo, NASA and the number 60 are stacked on top of each other above the continental United States, the curvature of Earth and the light of an approaching dawn. A light-blue and white arc shows the sunrise, which NASA says, "symbolises opportunity yet to come through exploration of the Moon, Mars and destinations far beyond."

There are also two vectors - red and blue - which form a number six. The blue is said to represent NASA's roots in aeronautics research, while the red represents the administration's leadership of an exploration program. The crescent moon, ringed planet and field of stars symbolise NASA's focus on science.

The new logo is NASA's fourth commemorative artwork, sitting alongside those created for the 25th anniversary in 1983, the 40th anniversary in 1998 and the 50th anniversary in 2008.



The stacked NASA and 60 evokes physicist Isaac's Newton's phrase: "standing on the shoulders of giants"

Jupiter's weird switching jet stream could be caused by gravity waves

An explanation for the regular reversal of the gas giant's atmosphere could have implications for our understanding of Earth's weather

Jupiter's powerful jet streams could be regularly changing direction due to gravity waves, according to a new study. Research suggests that gravity waves climb the gas planet's stratosphere and force the equatorial jet stream to reverse every four years. If confirmed, scientists will be understandably excited, as this would not only help solve a decades-long mystery, but it could also help explain extreme weather patterns on Earth.

The new study centred on the jet stream flowing east to west on Jupiter, referred to as the quasi-quadrennial oscillation (QQO). Scientists were able to examine it over five years using the Texas Cross Echelle Spectrograph mounted on NASA's Infrared Telescope Facility in Hawaii, and they could compare the data gleamed with simulations. In doing so, they found gravity waves produced by convection low in the atmosphere were causing the QQO as they rose.

Heat energy moves up through Jupiter's lower atmosphere and produces gravity waves

© NASA

Since the equatorial jet stream also reverses direction every 28 months here on Earth and changes the weather conditions, the findings have widespread implications for our understanding of this equatorial phenomenon. "We gained a better understanding of the physical mechanisms coupling the lower and upper atmosphere in Jupiter, and a better understanding of the atmosphere as a whole," says Raul Morales-Juberias at the New Mexico Institute of Mining and Technology. Our planet's jet stream was first discovered following the eruption of Krakatoa in Indonesia in 1883.

SpaceX's top-secret mission succeeds

SpaceX successfully launched a secret government satellite mission on its Falcon 9 rocket. Code-named Zuma, it blasted off from Cape Canaveral Air Force Station on 9 January with the booster's two stages separating two minutes and 19 seconds into flight.

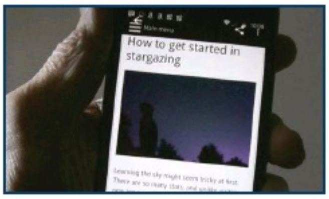
© SpaceX

Ancient stone structure may depict Earth's making

A 1,000-year-old stone structure in Mexico may have been created as a miniature model of the universe. Researchers say the shrine - located in the middle of a pond near the Iztaccihuatl volcano - represents the creation of Earth and the universe.

China to land on Moon's far side

China will seek to complete the first soft landing on the far side of the Moon later this year when it launches the Chang'e 4 lunar probe. First it says it will launch a relay satellite, allowing data to be replayed between controllers on Earth and the Chang'e lander and rover.



Society for Popular Astronomy relaunches website

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An artist's impression of the surface of Chariklo and its rings

©ESO/L. Calçada/Nick Risinger

Ringed object may reveal gas planet secrets

The structure of Chariklo's rings has been more closely examined to shed fresh light on the world

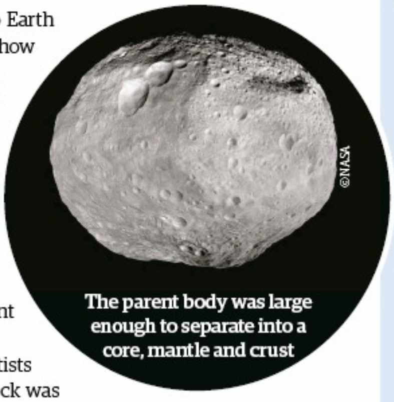
Astronomers appear closer to discovering how the rings around the largest confirmed minor planet of the outer Solar System came to be formed. Fresh observations of Chariklo, the centaur which orbits the Sun between Saturn and Uranus, have confirmed there are two thin, circular rings about nine-miles apart. But, just as exciting, they show a stark similarity with the alpha, beta or epsilon rings of Uranus. In other words, they have the same degree of eccentricity, and sharp edges that are denser than the centre.

Having observed 12 successful occultations by Chariklo between 2014 and 2016, scientists have ruled out that the rings were spewed from the centaur itself, and that there is no moon keeping the inner ring sharp. The researchers now think the rings could have come from the destruction of an early moonlet. Diane Bérard, a researcher at the Paris Observatory, tells **All About Space** that a passing object may have slammed into Chariklo and created the moon. Alternatively, its gravity swept up the rubble as it travelled through space.

Ever since Chariklo was found to have rings in 2013, it has turned theories on their head. Up until that point, it had been believed that rings could only be stable around bodies more massive than the centaur. The rings are studied by observing Chariklo as it passes in front of a star, allowing astronomers to view the areas of light that are being blocked.

Discovered meteorite "came from unknown asteroid"

Research reveals that a meteorite spotted by a network of cameras in Australia did not come from the Vesta family



The parent body was large enough to separate into a core, mantle and crust

©NASA

Fresh studies of a meteorite which fell to Earth over Australia more than ten years ago show that it came from a previously unknown parent asteroid. It had been thought that Bunburra Rockhole, which arrived on our planet on 21 July 2007, had come from a large group of meteorites that had broken off Vesta, the second-largest body in the Asteroid Belt between Mars and Jupiter.

Closer examination showed the meteorite's oxygen signature was different to those of Vesta, even though the bulk composition was similar. It has led scientists to consider three possibilities: that the rock was contaminated, that it came from an unsampled part of Vesta or that it is actually from a differentiated asteroid that has yet to be discovered.

Yet the first two potentials were soon ruled out, leaving just the third and most exciting one. "Either there is another big asteroid that we haven't found yet," says lead scientist Gretchen Benedix, a geologist at Curtin University in Australia, "or the asteroid that Bunburra Rockhole originated from has evolved over time through space weathering and impact processing."

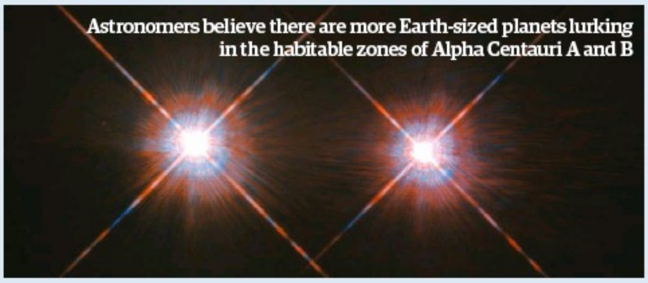
The scientists now say that it is likely Bunburra Rockhole's parent body formed in a similar part of the Solar System as Vesta, but that it would have been slightly smaller than the latter. They also say Bunburra Rockhole is a basalt meteorite, which indicates that melting took place in the parent body when the layers became separated and the asteroid differentiated. Where it came from exactly, however, remains a mystery.

Top tech to reveal Earth-sized planets around Alpha Centauri

Astronomers are hopeful that advances in technology will capture images of worlds in the nearby star system

The number of images detected from Earth-sized planets in the Alpha Centauri system could explode in the next decade, thanks to the development of a new observation technology. Ruslan Belikov, an astrophysicist at NASA's Ames Research Centre in California, is working on a method which bounces light from stars and planets on to deformable mirrors within telescopes. This, he says, would alter the shape of their surfaces and correct imperfections, getting around the problem of light leakage, which can make exoplanets hard to spot.

Currently, astronomers use coronagraphs to block the light from stars in order to better see the exoplanets, but some systems - including the triple-star system Alpha Centauri - have more than one star and it is difficult to completely block the light from them all. "We hope to infuse our technology into future space telescopes to enable them to target Alpha Centauri and other binaries," Belikov says.



Astronomers believe there are more Earth-sized planets lurking in the habitable zones of Alpha Centauri A and B

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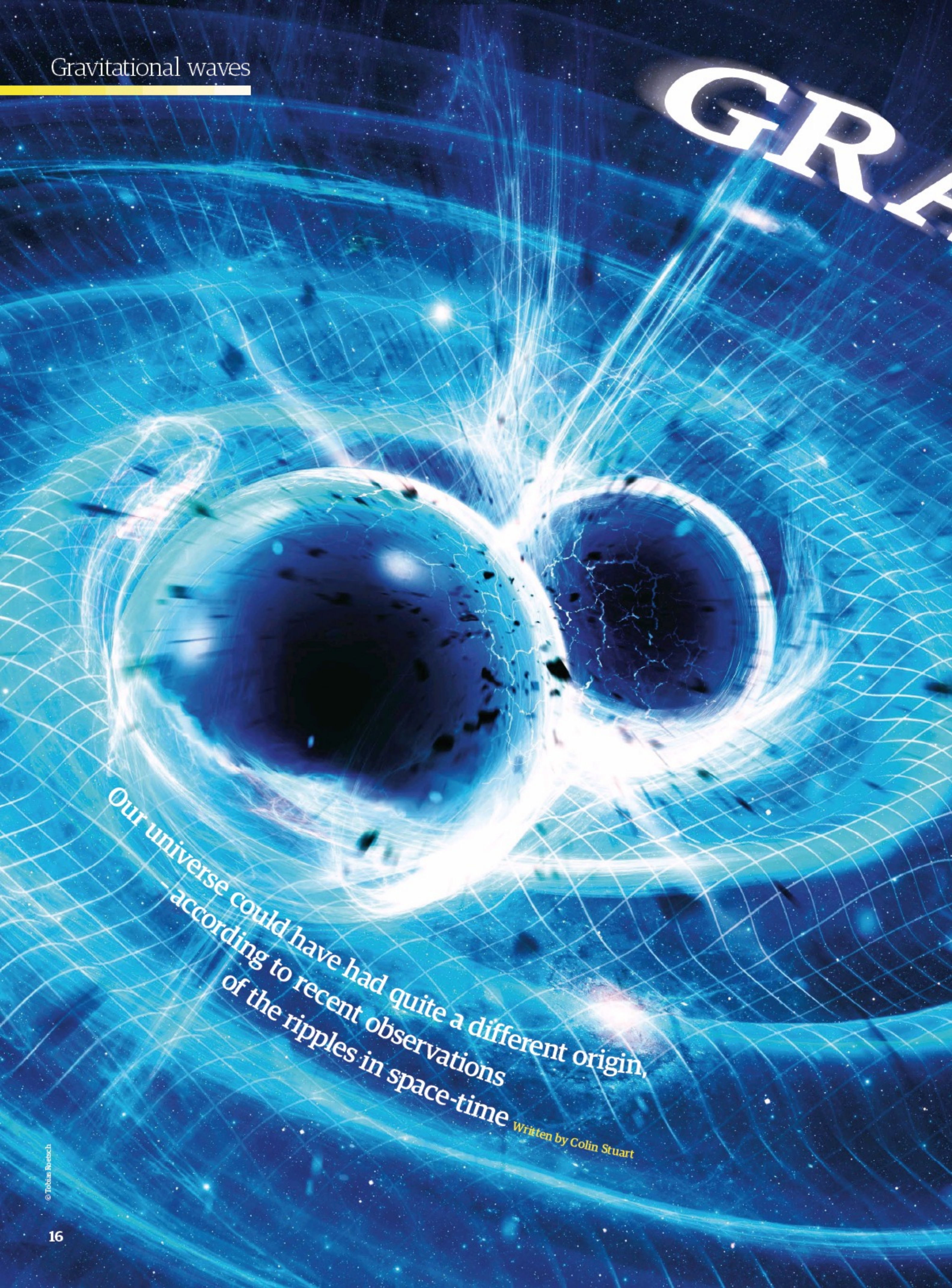


GRA

Our universe could have had quite a different origin, according to recent observations of the ripples in space-time

Written by Colin Stuart

© Tobias Roetsch

AVITATIONAL WAVES

DO THEY SUGGEST A BANG AT THE END OF THE UNIVERSE?

"How can something come from nothing?" It is one of the most common and thorniest questions related to the Big Bang. The most accepted theory of our universe's beginnings has it starting as an infinitely small, infinitely dense point that expanded outwards and cooled to become the modern cosmos. But what was the cause of this event nearly 14-billion-years ago? Even this is a question loaded with problems. If the Big Bang created time - as conventional thinking says - then you can't talk about 'before' or a prior cause, as those are notions that only make sense if time already existed.

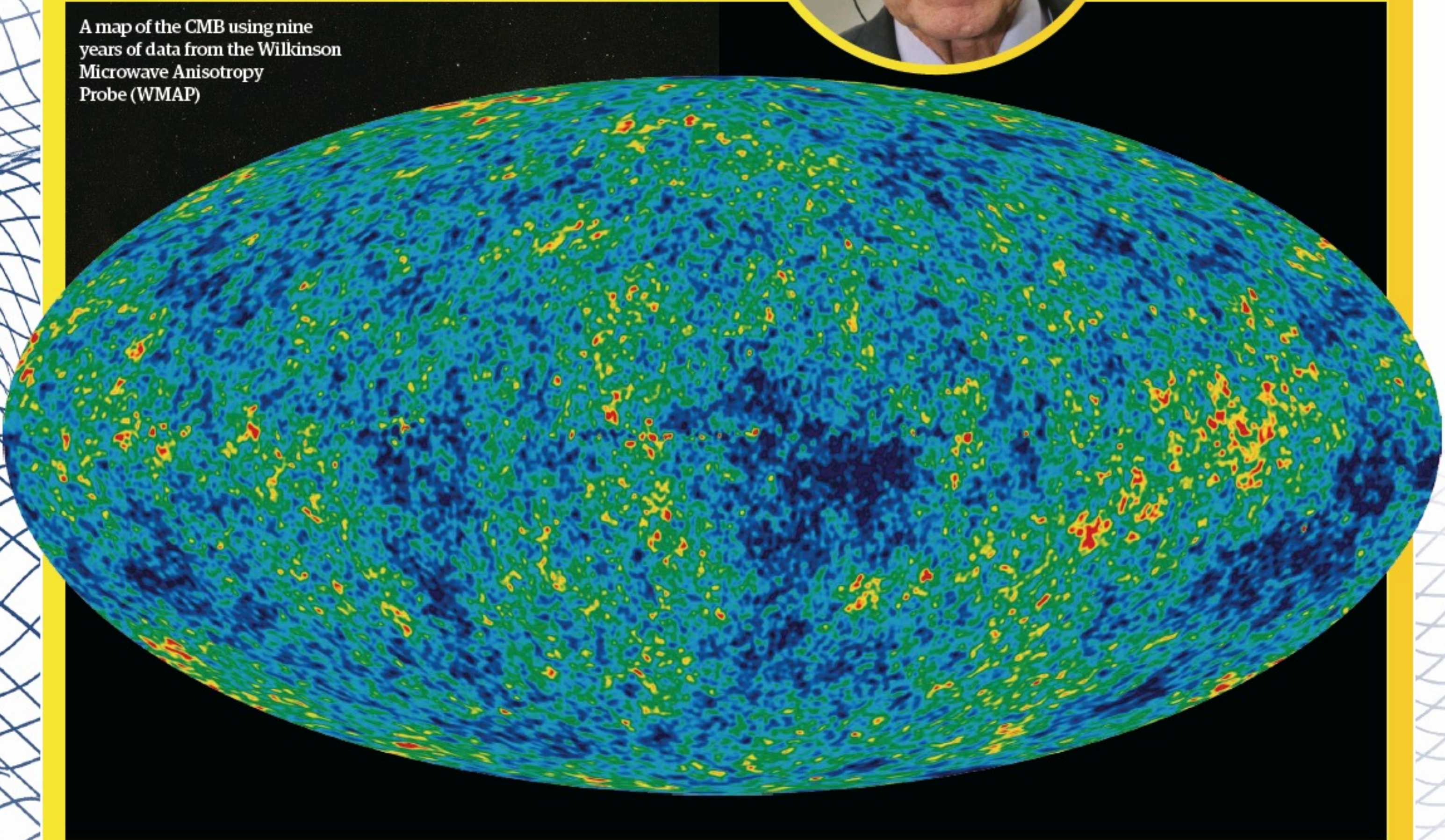
Sir Roger Penrose, long-time collaborator of Stephen Hawking, believes he has a way to banish these problems for good. What's more, astronomers might just have found evidence to confirm he's right. His theory is called Conformal Cyclic Cosmology (CCC), and it says that the explosive birth of our universe arose during the twilight years of another. There was a time before the Big Bang.

According to Penrose, there is "a mammoth in the room" that no cosmologist is currently addressing - how the early universe at the Big Bang was, in some ways, very similar to the state our universe is heading for in the distant future. In both cases, mass makes a significantly lower contribution to the total energy of the universe than it does today. To calculate kinetic energy - the energy of motion - you half the mass and multiply it by its velocity squared. In the first moments after the Big Bang, when the cosmos was very hot, particles were flying around stupendously fast. That means their speed made the majority contribution to the universe's total energy, not their mass.

The same can be said of the universe's future. In 1998, physicists discovered that the universe was expanding at an ever-increasing rate, shaking the astronomical community to its core. They had expected the cosmos to be slowing down as the power of the Big Bang waned. So, for the expansion to be accelerating again, astronomers believed there must be some invisible entity - known as dark energy - pushing everything apart. Eventually, all matter in the universe will be separated to such a great extent that mass again becomes a trivial factor in the overall energy of the cosmos.

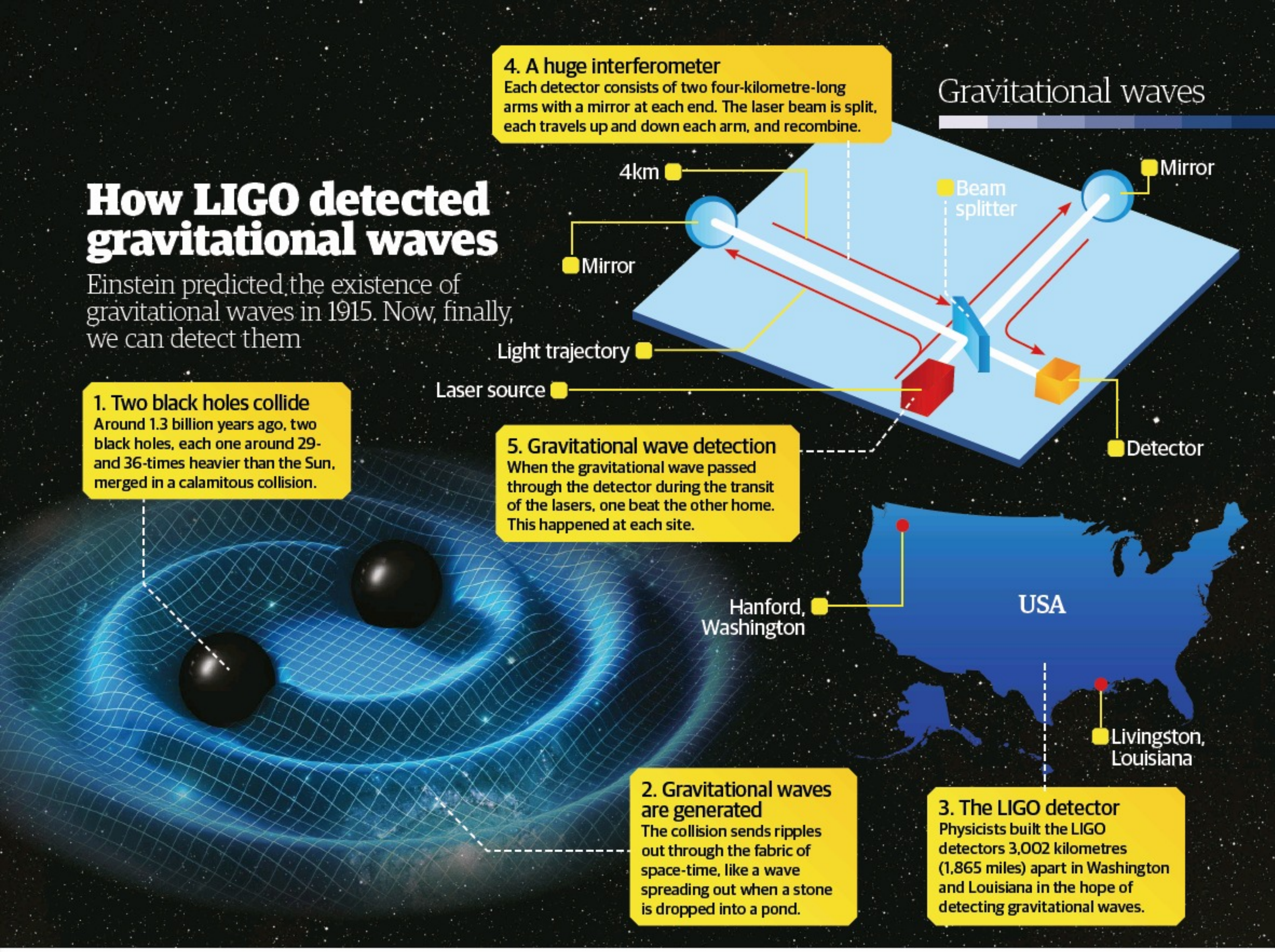
In both cases the universe will eventually be dominated by light, not matter. And for a photon (a massless particle of light) time and length does not exist. Ride along on a photon and you'd zip across the visible universe in literally no time. That insight was Penrose's key breakthrough. "In both cases the universe doesn't know how big it is," he says. As far as the universe is concerned, its hot, small beginning is physically identical to its cold, huge future. That in itself isn't controversial, but Penrose goes a step further. "This remote future becomes another Big Bang," he says. So what happened before the Big Bang? According to Penrose another universe ended, and that universe sprung from the death of yet another. Penrose calls each period an "aeon." The aeons go further and further back in time with no need for an initial beginning.

> "If the Big Bang created time then you can't talk about 'before' or a prior cause, as those are notions that only make sense if time already existed"


A map of the CMB using nine years of data from the Wilkinson Microwave Anisotropy Probe (WMAP)

How LIGO detected gravitational waves

Einstein predicted the existence of gravitational waves in 1915. Now, finally, we can detect them



1. Two black holes collide
Around 1.3 billion years ago, two black holes, each one around 29- and 36-times heavier than the Sun, merged in a calamitous collision.

2. Gravitational waves are generated
The collision sends ripples out through the fabric of space-time, like a wave spreading out when a stone is dropped into a pond.

3. The LIGO detector
Physicists built the LIGO detectors 3,002 kilometres (1,865 miles) apart in Washington and Louisiana in the hope of detecting gravitational waves.

4. A huge interferometer
Each detector consists of two four-kilometre-long arms with a mirror at each end. The laser beam is split, each travels up and down each arm, and recombine.

5. Gravitational wave detection
When the gravitational wave passed through the detector during the transit of the lasers, one beat the other home. This happened at each site.

In some ways it's a return to the steady state model that prevailed before the Big Bang gained significant traction in the mid-20th century.

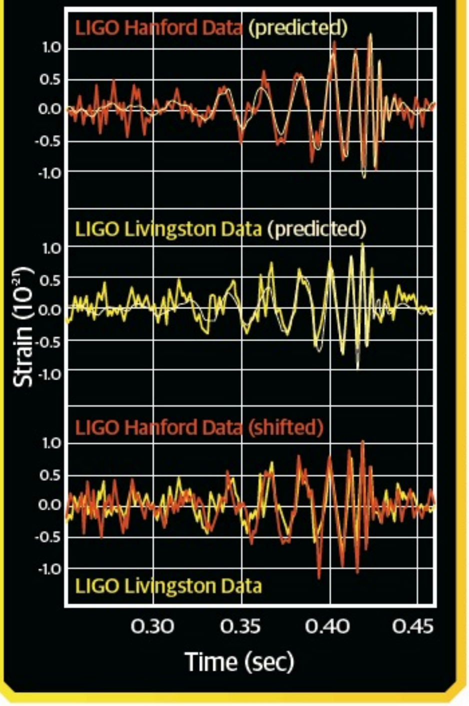
He admits it's a "wild suggestion", but believes that like all good scientific theories, it might be tested through experiment and observation. These tests stem from the idea that our aeon and the one preceding it were not completely isolated from one another. "Information does get through," he says. "It gets through in the form of a shock wave in our universe's initial dark matter." Dark matter, like dark energy, is a shadowy substance, this time needed to account for the way structures such as galaxies and clusters of galaxies formed in the early universe. According to Penrose's calculations, that shock wave would have had an effect on the Cosmic Microwave Background (CMB) - the leftover radiation from the Big Bang, released when the universe was under 400,000-years-old. "You'd see rings in the CMB that are slightly warmer or cooler than the average temperature," he says.

An aerial shot of the Virgo detector, near Pisa, Italy, showing one of its three-kilometre arms

The equations of CCC predict that a shock wave arriving from a previous aeon would have dragged matter into our universe behind it. If that caused material to head towards us, we would see light from that region shunted to shorter wavelengths - an effect astronomers call blueshift. Equally, a region carried away from us by a CCC shock wave would be redshifted - its wavelength would be stretched out. Blueshifted regions would appear hotter and redshifted areas cooler. It's these changes Penrose believes we'd see as rings in the Cosmic Microwave Background. Multiple shockwaves might even have produced a series of concentric rings. "I asked whether anyone had looked for these rings in the sky," says Penrose.

Several years ago it did seem as if those rings had been found, a veritable smoking gun for CCC. "Except nobody believed us - they said it must have been a fluke or something," says Penrose. "But those signatures have been confirmed by alternative groups," says Vahe Gurzadyan from the Yerevan Physics Institute in Armenia and Penrose's long time collaborator on CCC. They point to the fact that a team of Polish and Canadian researchers confirmed the presence of the rings to a confidence

The results



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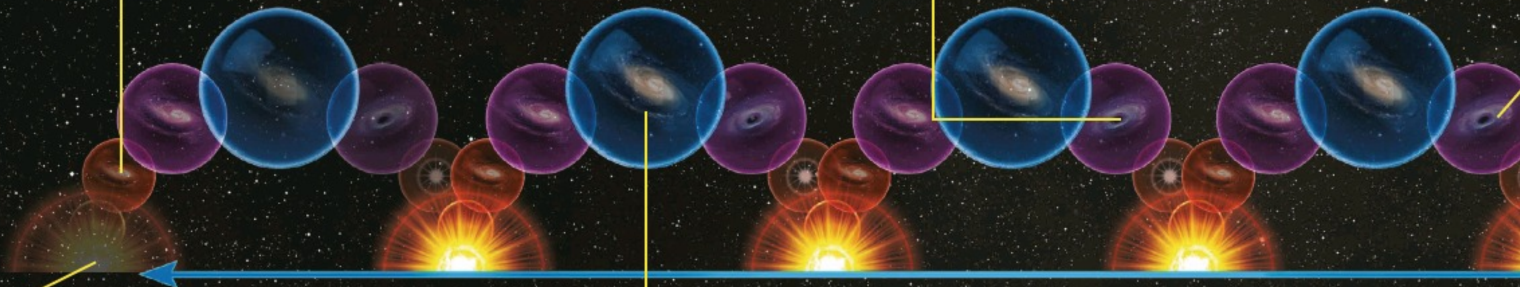
Two types of never-ending universe

An unusual idea, it might allow us to talk about a time before the Big Bang

Classic cyclic universe



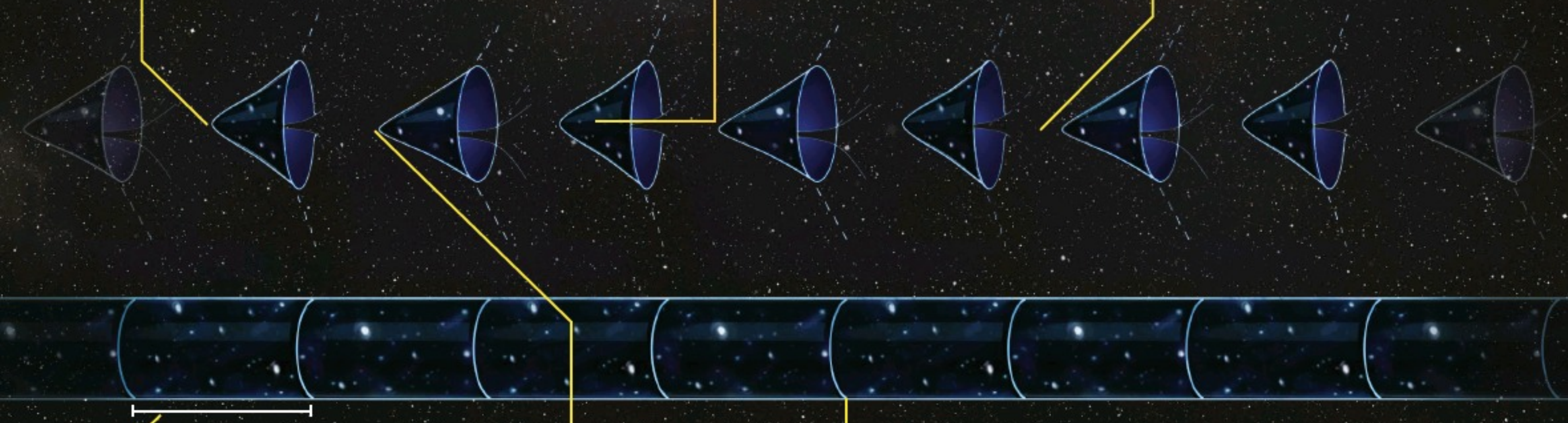
The first galaxies form
As the expansion continues, visible matter is drawn towards invisible dark matter to create the first structures in the universe.

Gravity takes over
The universe starts to shrink as gravity draws the galaxies back together, in a reversal of the period after the Big Bang.

The Big Bang
Nearly 14-billion-years ago our universe explodes into existence from an infinitely small, infinitely dense point called a singularity. This event is called the Big Bang.

Expansion doesn't continue forever
The universe continues to expand, but at an ever-slowing pace, as the collective gravity of all its galaxies applies the brakes. It reaches a maximum size.

Conformal cyclic cosmology



The Big Bang
The beginning of our universe takes place almost 14 billion years ago. Dark-matter particles called erebons are formed from the crossover with the previous aeon.

The expansion
Several billion years after the Big Bang the expansion rate of the universe begins accelerating again due to dark energy.

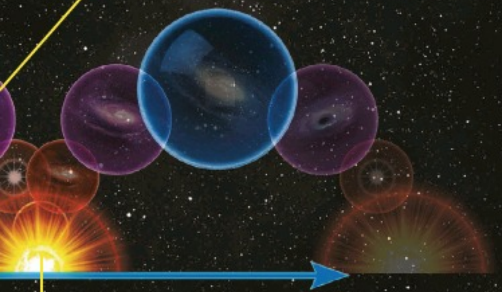
Things get eerily familiar
As far as the universe is concerned its cold, huge future matches its small, hot beginning and the same processes take place.

Adding up the aeons
The gap between two Big Bangs is known as an aeon. There have been countless aeons before ours, stretching back infinitely through time.

The second Big Bang
Another Big Bang takes place, creating a new universe that will eventually expand until yet another Big Bang occurs.

Things get dark at the crossover
The crossover between aeons creates a shock wave in the early dark matter of the new universe, potentially leading to an observable effect in the Cosmic Microwave Background.

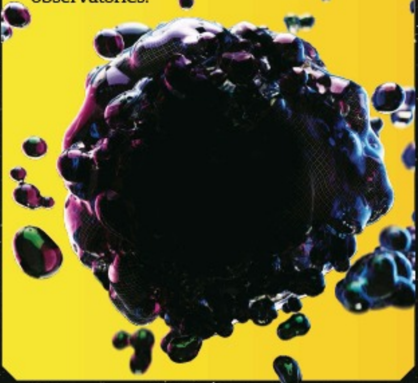
Galaxy collisions and black holes
Galaxies begin to collide with each other and the universe gets smaller, black holes form as matter is crunched together.



The Big Crunch and second Big Bang
Eventually everything is crushed down into a single singularity, which then explodes in another Big Bang to create a new universe.

How dark matter fits in

The equations of CCC predict that a new material should be formed at the crossover between aeons. This is the initial form of our universe's dark matter, and Penrose calls these particles erebons. As they decay they produce gravitational waves, which we may now be able to detect using gravitational wave observatories.



The modern Big Bang theory was first suggested by Georges Lemaitre in the 1920s

> "As far as the universe is concerned, its hot, small beginning is physically identical to its cold, huge future"

level of 99.7 per cent. However, there are still many doubters. Gurzadyan remains steadfast. "These structures are real - there is no doubt that our calculations are reliable and correct," he says. Still, Penrose has been exploring other approaches that might sure up the pair's claims about CCC and a time before the Big Bang.

The transition between aeons would do something more fundamental that just create a shock wave in our dark matter and rings in the Cosmic Microwave Background. "A new material, the dominant material in the universe, is created at the crossover." Penrose regards that new material as the initial form of dark matter itself. "But in order that it doesn't build up from aeon to aeon it has to decay," Penrose says. He calls these initial dark-matter particles erebons after Erebos, the Greek god of darkness. On average it would take 100 billion years for an erebon to decay, but there are some that will have decayed in the 14-billion-year history of our universe. Crucially, as they decay, Penrose says erebons dump all their energy into gravitational waves.

Gravitational waves are distortions in the fabric of space-time, predicted by Einstein over a century ago as part of his General Theory of Relativity. For most of that century we didn't know if gravitational waves even existed. But, that changed on 14 September 2015, when physicists using the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced the detection of gravitational waves arriving at the Earth, from two black holes which had smashed together at nearly one-half the speed of light. Several other detections have followed, including more black hole mergers, along with the collision of two neutron stars - the collapsed cores of massive stars (but are too small to form black holes) that have gone supernova.

Last summer the astronomical community was buzzing with rumours that these detections might not have been what they seemed after all. A team from The Niels Bohr Institute in Copenhagen published a paper suggesting that the signals were not gravitational wave events, but ghosts in the data instead. By the time a gravitational wave makes it to the Earth its signal is very weak, making it difficult for physicists to pick out these disturbances above the background 'noise' of more mundane terrestrial events that might also wiggle LIGO's sensitive mirrors. If the same signal is picked up by both detectors, that is a massive clue that it has come from space. The noise, however, should not be correlated in the same way. A truck trundling by in Washington State should not affect the other detector over 3,000 kilometres (1,864 miles) away in Louisiana.

The Copenhagen team performed their own independent analysis of the LIGO data and found that the noise was indeed correlated too. LIGO

LISA Pathfinder spent 16 months in space as a gravitational wave laboratory until July 2017

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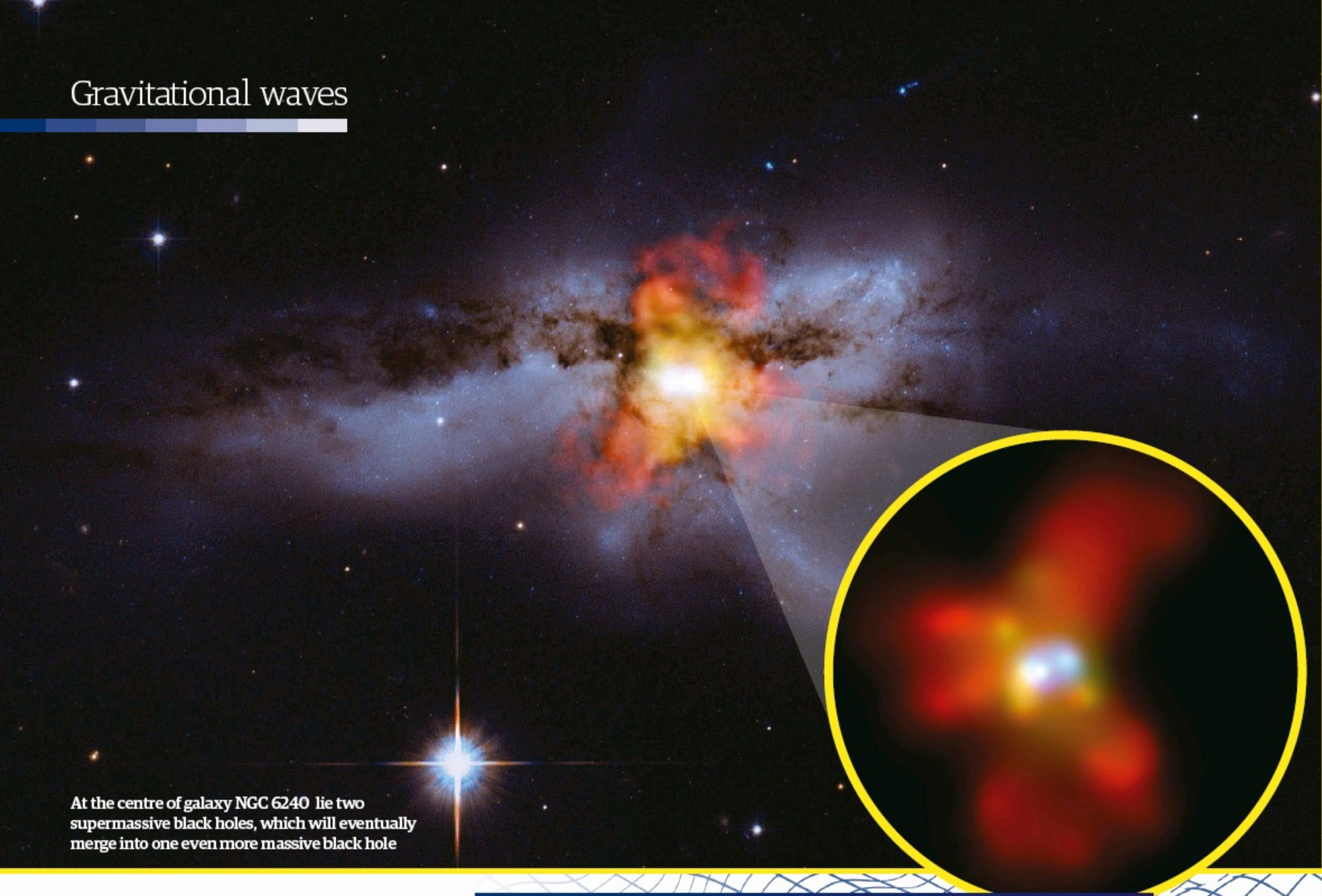


At the centre of galaxy NGC 6240 lie two supermassive black holes, which will eventually merge into one even more massive black hole

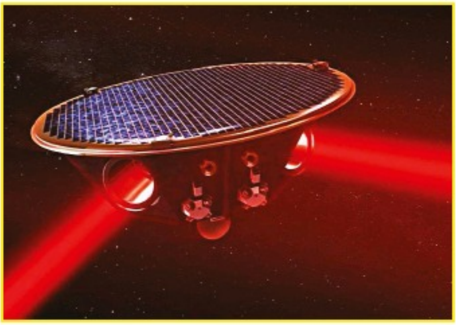
physicists may have been fooled into thinking they were picking up gravitational waves when they weren't. Perhaps there was something up with the detectors that meant they produced gravitational wave signals where none existed. The Copenhagen paper was met by a swift rebuke from Ian Harry, a physicist at the Max Planck Institute for Gravitational Physics in Germany and a member of the LIGO team. He argued that the Copenhagen team hadn't performed their analysis correctly – there was no correlated noise.

When Roger Penrose heard about this saga he thought more about what could be causing any correlated noise. "Maybe they are seeing erebon decay," he says. He soon published his own paper setting out more details behind his claim. The arrival of gravitational waves from erebon decay would be correlated between the two detectors, as the waves meet one before reaching the other. Yet as they'd have nothing to do with black holes or neutron stars, they might be dismissed as noise. Indeed, Penrose argues that what the Copenhagen team found isn't correlated terrestrial background noise, but correlated noise from background erebon decay out there in the universe.

> "The equations of CCC predict that a shock wave arriving from a previous aeon would have dragged matter into our universe behind it"

So how likely is that to be the case and CCC to be the right approach to the troublesome questions surrounding the Big Bang? "It's classic Roger Penrose," says Andrew Pontzen, a cosmologist at University College London. "It's a very thought-provoking idea that brings together a lot of very clever strands into a really nice vision for the way the universe could behave over extremely long timescales," he says. "It's a beautiful theory and it deserves a lot of attention." However, Pontzen points out that the original data analysis on the CMB rings – Penrose's first proposed test of CCC – was "quite badly flawed" and "reached conclusions that couldn't really be supported." Similarly, he supports the conclusions of the LIGO collaboration, which found that the correlated noise between its detectors isn't real, and so can't be caused by erebon decay. "Data analysis is tremendously subtle. There are these pitfalls that are waiting to be fallen into," he says.

That doesn't mean CCC is wrong, but it does appear that compelling evidence for its veracity has yet to be found in either the CMB or the LIGO gravitational-wave detectors. Even if the correlated noise trumpeted by the Copenhagen team is fictitious, future gravitational-wave detectors might pick up correlated noise from erebon decay. "I'm hopeful that it might be possible to see these effects from distant galaxies," says Penrose. "If so, it would give you a remarkable way of telling the dark-matter distribution across the universe. It might also allow us to talk about a time before the Big Bang."



LISA is scheduled to launch in 2034 and aims to measure low-frequency gravitational waves

In October 2017, the crashing of two neutron stars produced detectable gravitational waves and light

© NASA; ESA; NASA/Swift/Dana Berry; Getty Images / Handout

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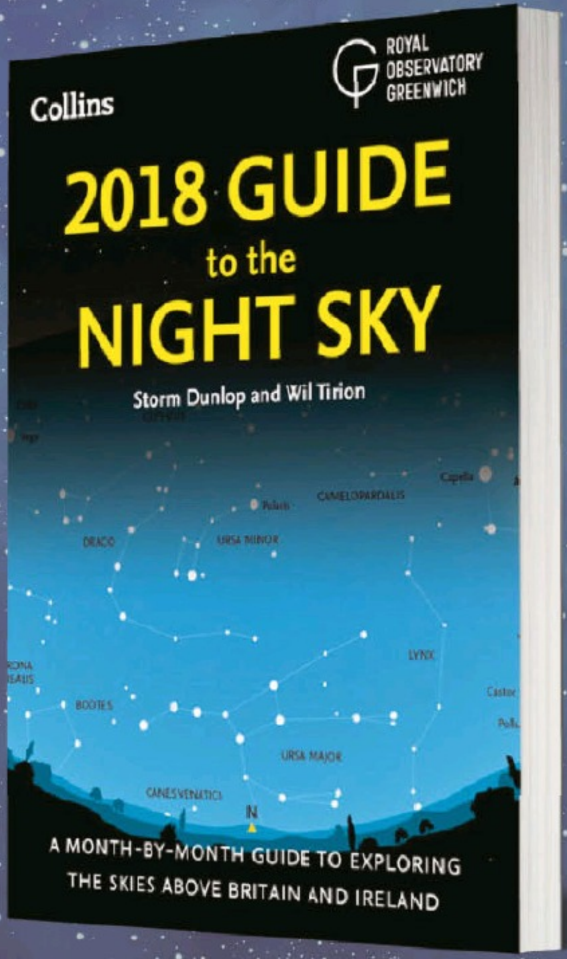
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Collapsible systems
As well as OSS, Magna Parva are looking to print carbon fibre booms in space and Bigelow Aerospace are working on inflatable habitats.

Panel ridge origami
While traditional origami works by creasing material, OSS do not want creases in the antenna surfaces. The membrane is thickened along the fold lines, so it bends but doesn't crease.

Origami spacecraft

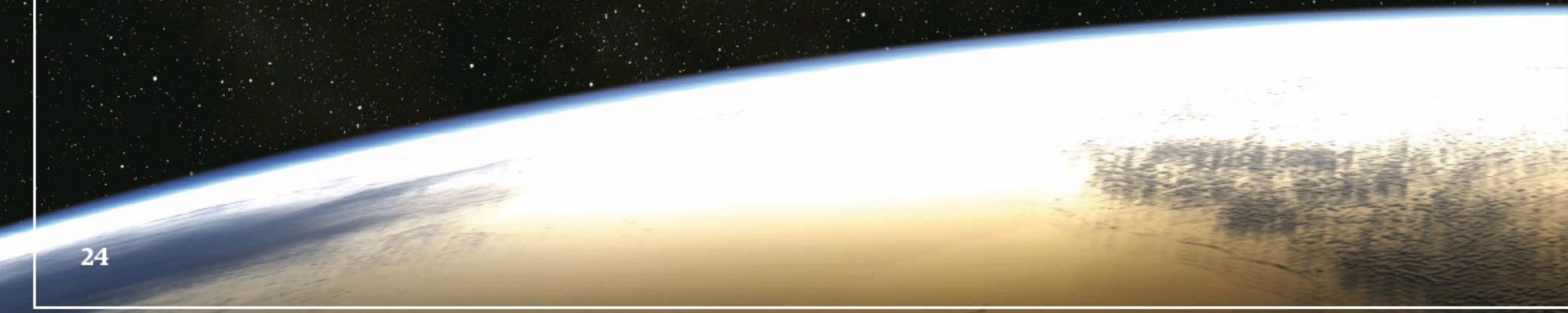
A British space technology company is using ancient Japanese paper folding to pack up missions

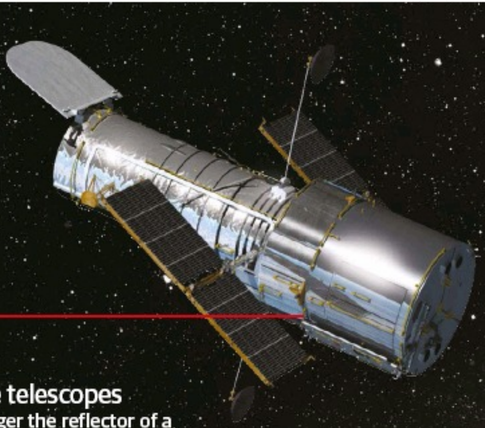
NASA's next great observatory, the James Webb Space Telescope, will be 12 years late with a cost of $8.8 billion. One of the contributing factors has been the need to pack a huge 6.5-metre 18-piece telescope mirror (Hubble's is a single piece with a 2.4-metre diameter) away in a 5.4-metre diameter rocket (Ariane 5). In the near future, British start-up, Oxford Space Systems hopes to enable much larger structures to be more conveniently (and cost effectively) launched into space, and they are studying origami, the ancient Japanese art of paper folding, to help them.

Oxford Space Systems (OSS) was founded in 2013 by engineer Mike Lawton, after he spent some 16 years working in the British space industry. OSS specialise in deployable space structures – the booms and panels that make up satellites and space stations and foldable antennae for communications. With launch costs ranging from around $50 to $500 million, it is very important to minimise the total mass you need to launch, to reduce these costs. This is what led OSS to origami. "To work out the best way to fold these space systems to fit inside a launch rocket, we had to ask ourselves: has anyone figured out a really smart way to fold things? The answer was yes – origami experts – and it turns out they've been doing it for a really long time," says Lawton.

While researching the field, Lawton came across Professor Zhong You of Oxford University. You was fascinated by OSS's challenges and immediately invited Lawton to his laboratory. "We didn't leave his office for four hours that day, spending most of the morning looking around his laboratory. It was like a toy shop, and was full of exciting prototypes and fantastic concepts!" Origami is actually very amenable to mathematical modelling, providing a useful design tool for spacecraft development; though Professor You starts with physical experimental structures before working backwards to define their mathematical characteristics.

OSS' current focus is on creating foldable antennae, which will be up to 12 metres in diameter once deployed. However, unlike





Space telescopes
The larger the reflector of a telescope, the better its light gathering capability. Hubble's 2.4-metre mirror meant it was able to fit in the Space Shuttle, with folded solar panels.

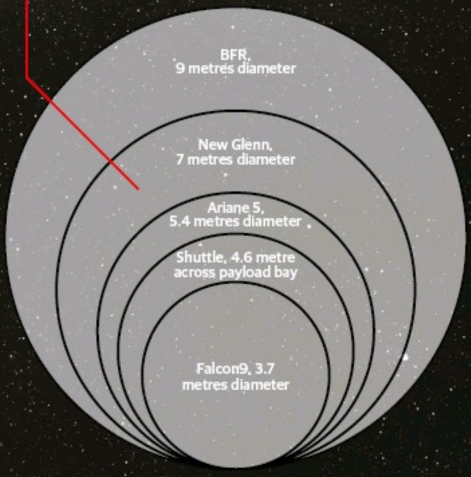
Antennae
The bigger the antenna, the better it works, as it can focus signals from a larger collection area. OSS's collapsible antennae would speed up space-based communications.

traditional origami they are specifically trying to fold the material without creasing it. Lawton explains: "We're adding thickness to the folds. We're working with an advanced type of origami because it involves much more complex mathematics – panel-ridge origami." Ultimately though, OSS want to move beyond one-off prototypes and onto the mass production of standardised collapsible components. "We're developing tech that targets constellations – thousands of satellites in space for internet and other services – and I want to make sure that it's our tech developed in the UK that's the most contracted presence in these constellations," Lawton says.

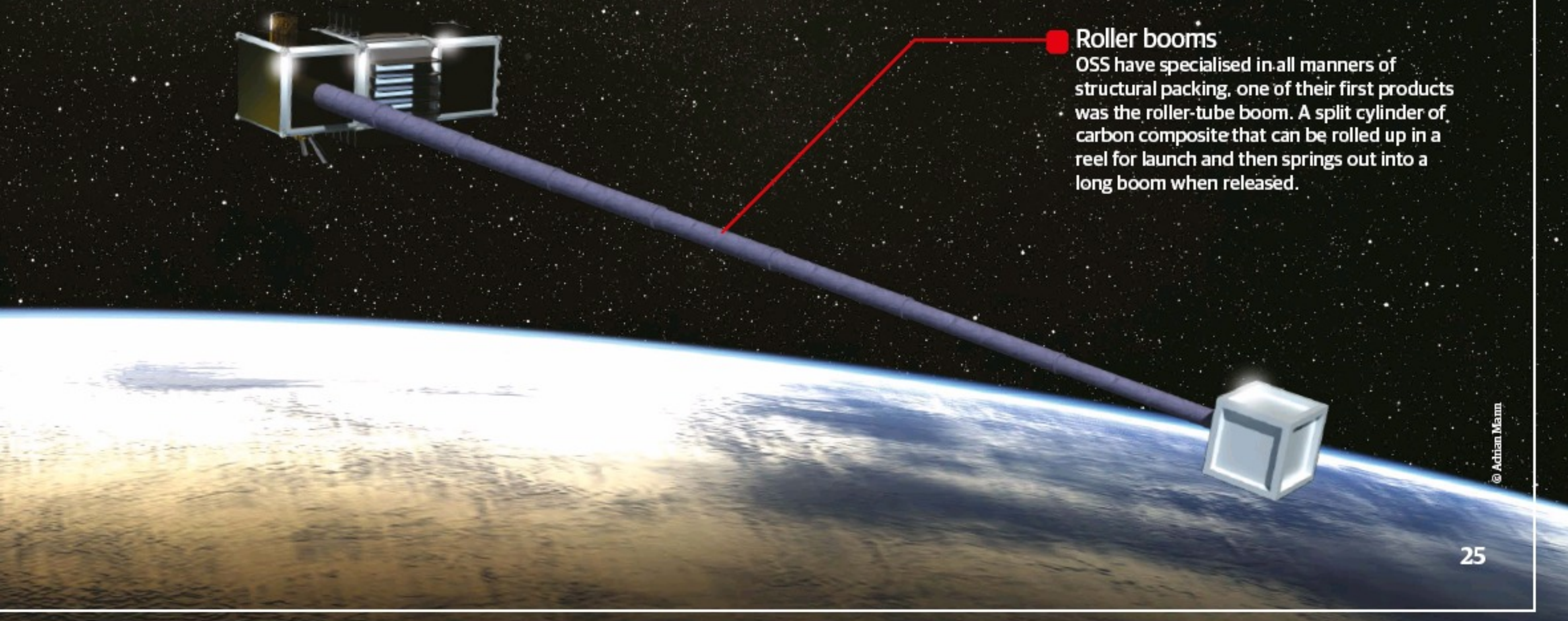
Oxford Space Systems' ingenious designs seem a natural complement to other expandable technology, like Magna Parva's printed-in-space carbon fibre beams and Bigelow Aerospace's inflatable habitats. Together they could fit extraordinary spacecraft into existing launch vehicle payload fairings, but perhaps the most intriguing possibility is what they could do with SpaceX's Big Falcon Rocket. Predicted to replace SpaceX's existing Falcon 9 rocket and Dragon capsule, the fully reusable BFR will be nine-metres in diameter and could launch the James Webb mirror in one piece. Imagine what we could do if we combined these new technologies to fit huge structures into large rockets, with a huge rocket!

> "Origami is very amenable to mathematical modelling, providing a useful design tool for spacecraft development"

Cargo cross sections
Space-race era spacecraft tended to be dedicated designs, but now most payloads are launched in standardised payload fairings or cargo bays.


BFR, 9 metres diameter
New Glenn, 7 metres diameter
Ariane 5, 5.4 metres diameter
Shuttle, 4.6 metre across payload bay
Falcon9, 3.7 metres diameter

Roller booms
OSS have specialised in all manners of structural packing, one of their first products was the roller-tube boom. A split cylinder of carbon composite that can be rolled up in a reel for launch and then springs out into a long boom when released.



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Behind the scenes ESA with Tim Peake

Following his successful six-month Principia mission, Tim Peake is carrying out new duties for the European Space Agency (ESA) ahead of his next flight into space. We caught up with the UK astronaut at the European Astronaut Centre in Cologne to find out more

Written by Nick Spall

More than two years on from his launch to orbit aboard the Soyuz TMA-19M spacecraft from the Baikonur Cosmodrome in Kazakhstan, 45-year-old Tim Peake looks incredibly fit and well. He spent six months in microgravity, completing 2,720 or so orbits at around 27,000 kilometres (16,777 miles) per hour, 400 kilometres (248 miles) above the Earth on the International Space Station (ISS), yet he is now almost fully back to his pre-flight fitness and body strength, eager to be allocated his next mission assignment.

During this post-flight period, Tim found time to write and publish two books covering his space flight: *Hello, is this planet Earth?* as a compilation of the best of his own photos taken from orbit, plus the excellent *Ask an Astronaut,* which describes in great detail what it takes to be selected for astronaut training, and how it feels to experience the rigours and wonders of spaceflight. Tim's proceeds from both books are donated to The Prince's Trust charity, for which he is an ambassador.

Following some time in Houston for post-flight medical reviews and debriefing, Tim moved back to the European Astronaut Centre (EAC) with his family to take up the position of head of crew support, a post now called 'astronaut operations team lead'. In this role, he looks after all aspects of the ESA astronaut requirements during their missions on board the ISS.

> "I didn't ever feel the need to hang on to the station when outside, even though we keep one hand on the rails a lot of the time" **Tim Peake**

Tim's wife and two sons are back to daily life living in Cologne, Germany with him at home regularly again - this contrasts to his six months on the ISS when his children would occasionally wave to him on the ISS as it passed them serenely overhead. Communications with ISS crews is excellent, and families can access the astronauts on a daily basis by tele-link and emails.

The EAC itself is a large campus-style complex located close to the main airport at Cologne. It includes various ISS module simulators, a Soyuz capsule basic trainer, a deep-pool Neutral Buoyancy Facility for EVA training, fitness rooms and general training facilities, plus astronaut and support crew staff offices. Several UK trainers work at the EAC, including Matt Day, whose responsibilities include providing instructional videos for ESA astronauts. These can be uploaded to the ISS for specific operations tasks in orbit - for example, one covered Tim's telerobotic link-up and control from orbit of the Exomars rover test vehicle 'Bridget' located at the 'Mars-yard' at Stevenage during his 'Principia' mission.

The effects of weightlessness are now much better understood than during the early Salyut, Skylab and Mir precursor space station days. Muscle mass and strength, bone mineral density and visual acuity degradation are now expected and catered for, following on from the initial Space Adaptation Syndrome (SAS) feelings of nausea that afflict many astronauts early after their arrival on the ISS.

Tim explains: "When I first arrived at the Space Station I did go through the expected period of feeling a fullness in my head, with a stuffy nose and mild headaches. This went away after a few hours, though, and I adapted very well to weightlessness. I did initially lose about 5 kilograms from my 70 kilogram body weight - with a careful diet and strength exercise I was able to recover that."

More than 50 per cent of astronauts on long-duration missions have experienced a noticeable loss of visual acuity, becoming far-sighted. Some have had to rely on reading glasses while in space and after their return to Earth. This is thought to be due to intracranial pressure increases in 'zero-g' and its effect on the optic nerve. The detailed process behind this change is still being investigated on the ISS, and the UK's Dr Robert Marchbanks is leading one particular experiment for this condition. Tim's eyesight did change in space, but this, his bone density and muscle loss changes have almost fully returned to normal.

Tim explains: "On the ISS my eyesight changed so that I did use the reading glasses that we had on board as a back-up. Now my eyesight is only slightly less than it was before launch - and as a 45 year old that may well be a natural change anyway and completely unrelated to spaceflight... my father used reading glasses when he was 45, for example!"

"All of the bone density loss I experienced - which was about two per cent overall - has now almost fully been restored, with my muscle strength fully back so that I am able to run long distances as much as I could pre-flight. The countermeasures we used on the ISS, including the ARED exercise machine, worked really well," he says.

As an experienced test pilot with over 3,000 hours of helicopter and fixed-wing flying, Tim could undertake the more dramatic aspects of spaceflight with ease. After, his nine-minute rocket ride into orbit, the difficult docking with the ISS that required spacecraft commander Yuri Malenchenko to use manual procedures at night, the four-hour 43-minute EVA spacewalk and the wild ride back on the Soyuz during re-entry were all exciting, but carefully trained for. Interestingly, it was the docking and berthing of the Dragon resupply freighter that Tim found most challenging:

"Capturing and docking the Dragon required great concentration and care... a mistake that close to the hull of the ISS would have been very serious. However, I found the robot arm controls familiar after years of helicopter control experience, and all went well."

As to the EVA, how did he feel outside the ISS, tethered to the guide rails and floating 400

Here Tim is helping with the Novespace/Rêves de Gosse campaign, giving some lucky European children with disabilities the chance to experience the thrill of zero-g parabolic flight onboard a converted Airbus A310

This was the trusty Russian Soyuz spacecraft that took Tim and his two colleagues Tim Kopra and Yuri Malenchenko to orbit in 2015. To the left is a docked Cygnus resupply craft

Floating in front of the ISS cupola window, Tim is reading Yuri Gagarin's book *Road to the Stars*, written after his 1961 spaceflight. This was a signed copy taken to the Mir space station in 1991 by the first Britain in space, Helen Sharman. It was signed by her Mir crew and then by Tim's ISS crew during his mission

©ESA

What Tim Peake did during Principia

Airway Monitoring

Studying the effects of dust particles and other detritus on the human respiratory system in a weightless environment.

Brain-DTI

Testing and understanding how an astronaut's brain reacts and functions when processing information and commands while they are weightless in the microgravity environment of space.

Circadian rhythms

Testing the levels of melatonin in the body and seeing how a drastically different day-night cycles affects Peake's sleep patterns.

Space headaches

Living in a highly pressurised chamber can cause serious headaches, so Peake and the crew will have to fill out questionnaires to determine the severity and cause of these space headaches.

Muscle biopsy

This study will determine the effect that being weightless for six months has on Peake's muscles, both before and after his time onboard the ISS.

Energy levels

Peake and the rest of the crew onboard the ISS will provide the ESA and NASA with data on how many calories an astronaut needs to function to the required standard.

Cartilage and osteoporosis

Peake will be closely monitored to see how the reduction of cartilage affects his bone density and the potential development of osteoporosis while weightless.

Skin degradation

The first ever space-based experiment focused on skin monitored the faster rate at which astronauts shed skin cells and examine the biological processes behind this.

Plasma

Creating an ionised gas known as plasma in space allows dust particles to behave more realistically than they would on the Earth. The aim is to understand atom interactions.

Blood cell function

To test the effects of bone marrow fat changes in a weightless environment, bone marrow was exposed to radiation and the results were monitored.

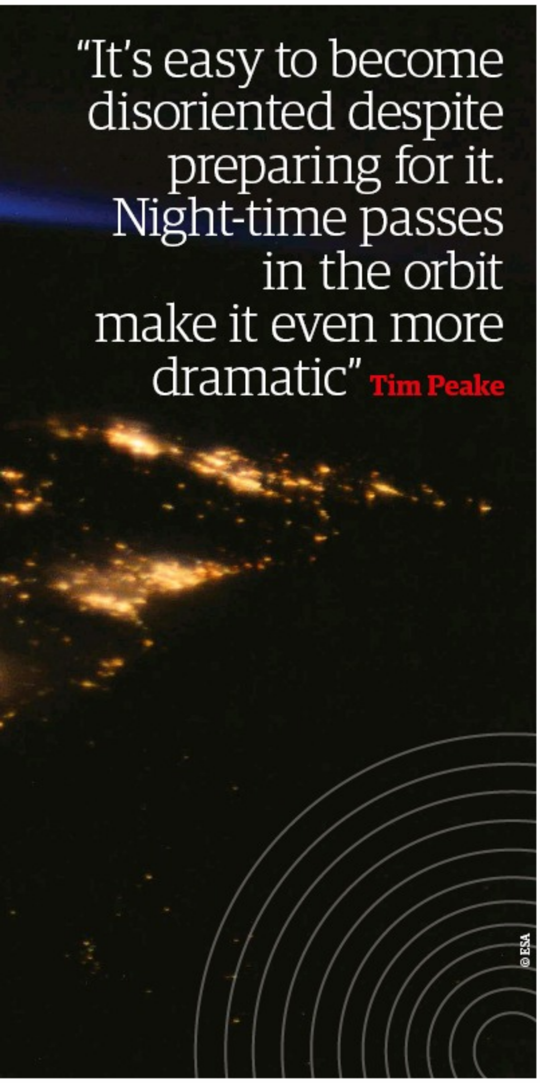
One of Tim's responsibilities included research with the Airway Monitoring experiment. This measured nitric oxide in exhaled air and is part of a study that may assist asthma sufferers one day

Tim's photo of the UK at night, 400km below. In orbit he experienced 16 night-time passes of the Earth every day. Below, his family, plus many others, often waved back as he went overhead!

kilometres (248.5 miles) above the Earth? "It is similar to our training in the buoyancy tank, and the safety tethers that you use give a feeling of security," he explains. "However, being 'upside-down' beside the lab modules, then reversing the position occasionally as part of the process of laying cables along the hull did require lots of focus, as it is a strange feeling. It's easy to become disoriented despite expecting and preparing for it. Night-time passes in the orbit make it even more dramatic. I didn't ever feel the need to hang on to the station when outside, even though we keep one hand on the rails a lot of the time."

Tim's hard work on the microgravity science research and outreach tasks of Principia as part of the ISS Expedition 46/47 has earned him widespread respect from both the national press and scientific community. He was involved in over 250 on-going ISS experiments, with over 30 closely covered during the Principia mission.

Some Tim found highly rewarding: "My probable favourite was ESA's Airway Monitoring experiment, which was challenging to execute using the space station airlock as a hypobaric chamber, and will benefit asthma sufferers here on Earth. The protein crystal growth experiment was one I would like to undertake again. It has the potential for huge benefits in drug development, and there is UK involvement in analysing the crystal structures after they return to Earth. This also applies to the Electro-Magnetic Levitator, where companies such as Rolls Royce in the UK are interested in its application for alloy turbine blade studies. As an ESA astronaut, I was closely responsible for running the Columbus research module in addition to being a specialist for the Japanese Space Agency's 'Kibo' laboratory. We do spend a lot of each intensive day on our own with lots of tasks, and often don't get to chat much – the interior volume of the ISS is about the same as a 747!"



> "It's easy to become disoriented despite preparing for it. Night-time passes in the orbit make it even more dramatic" **Tim Peake**

© ESA

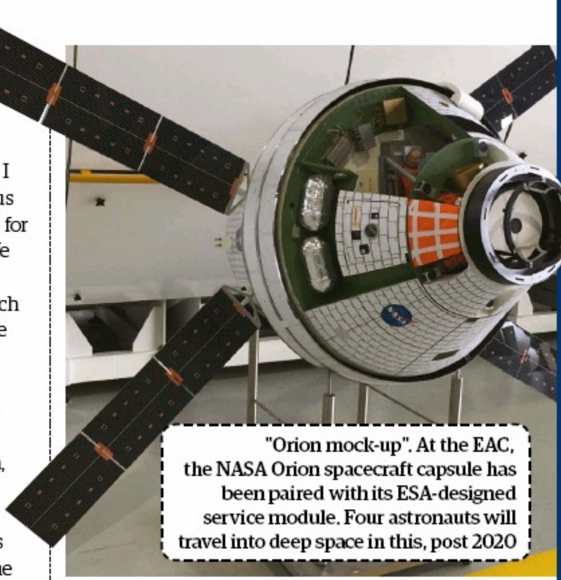
Since his return from space in June 2016, Tim has not only had to readjust to life on Earth physically and mentally, but has also had to continue the public outreach aspects of Principia, carrying on with post-flight visits to schools, colleges and institutions and giving public lectures as part of his STEM inspiration activities for young people. "It is generally accepted that the intensity of the public outreach work from Principia will be a hard one to follow for future missions!", he says. "Thanks to the great organisation and hard work of the UK Space Agency and ESA teams, we involved up to 1.6 million school children in over 30 projects, with 10,000 schools signing up and following the ISS activities."

Tim is currently awaiting his next spaceflight assignment. As an ESA astronaut from the intake group of six in 2009, he will be joining a new 'second flight' sequence to the ISS – all of the new astronauts have experienced missions to the space station, with only the relatively recently appointed German astronaut, Matthias Maurer, yet to make his first spaceflight.

In January 2017, ESA's director general Jan Wörner confirmed that Tim was due for a second mission to the ISS. The UK is the fourth-largest contributor to ESA and that, plus its recent involvement in human-spaceflight experiments on the ISS, will mean that Tim appears firmly in the line-up for the chance at a second flight. However, this assignment will take several years to realise. The current rate of one or two ESA astronaut visits to the Station per year, plus the need for a two-and-a-half-year specific training sequence post the actual mission assignment will mean that as of January 2018, it will most likely be several years before Tim could join the ISS standard complement of six crew members in orbit.

"At present, ESA's Paolo Nespoli is on board for his 'Vita' mission, with Alexander Gerst assigned to a 2018 flight, followed by Luca Parmitano in 2019. The ESA 2019 Ministerial meeting will consider future ISS commitments, most likely confirming missions to the ISS to 2024 and beyond. Therefore, the realistic earliest date for my next mission would be at least mid-2020," Tim tells us.

In recent years, post-retirement of the US Space Shuttle programme in 2011, ESA and NASA astronauts have had to fly to orbit aboard the venerable three-seater Soyuz capsules that have been operating for over 40 years. Soon though, the US will be bringing forward two new spacecraft to access the ISS via commercial agreements: the SpaceX 'Dragon V2' spacecraft with its Falcon 9 Block 5 launcher, and the Boeing CST-100 Starliner capsule that will be carried to orbit by an Atlas V rocket. These seven-seater spacecraft will be the mainstay of ISS operations through to beyond 2024 for low-Earth orbit access, and are due to begin crewed test flights in 2018.



"Orion mock-up". At the EAC, the NASA Orion spacecraft capsule has been paired with its ESA-designed service module. Four astronauts will travel into deep space in this, post 2020

Tim says: "It is likely that ESA astronauts will join the two US spacecraft for accessing the ISS via NASA barter agreements. This implies that I could one day take a seat in one of the US vehicles, rather than in the left- or right-hand seats of the Soyuz as previously occurred during my Principia mission."

ESA is currently committed to providing the service modules for the new four-seat Orion deep-space vehicles, which aims to one day take astronauts to Mars. Other current ESA plans are to take part in the Deep Space Gateway (DSG) operations, helping to crew the proposed modular station that will orbit the Moon in cislunar space. This will allow for a NASA-led international return to the Moon itself, with the possibility of then extending their reach to Mars.

Tim is now 45 years old, but astronauts can continue through their mid-50s and beyond – Paolo Nespoli, for example, is now 60 years old. This means that Tim could join ESA human-spaceflight missions possibly up to the early 2030s. By that time, joint international projects may mean that he will even be part of future lunar exploration, with the 'Moon Village' concept being a particular favourite of ESA's as part of its commitment to explore the Solar System.

ESA is also increasing its cooperation with China's National Space Administration, following a 2015 agreement to boost collaboration. In August 2017, astronauts Samantha Cristoforetti and Matthias Maurer joined 16 Chinese astronauts for nine days of joint sea-survival training off China's coastline. As a successor to its experimental predecessors Tiangong 1 and 2, China is planning a new larger modular station for launch and assembly post 2020.

For Tim Peake, assuming the UK government continues to support ESA, the prospects of future flights – and possibly for new UK astronauts – to the ISS, perhaps the emerging Chinese station or even to the DSG lunar orbit outpost, certainly look good.

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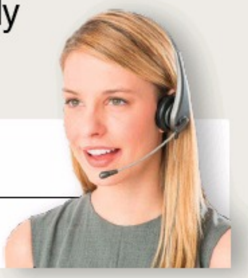

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Explorer's Guide

Neptune

The most distant planet in our Solar System tells a cold, turbulent and quizzical story

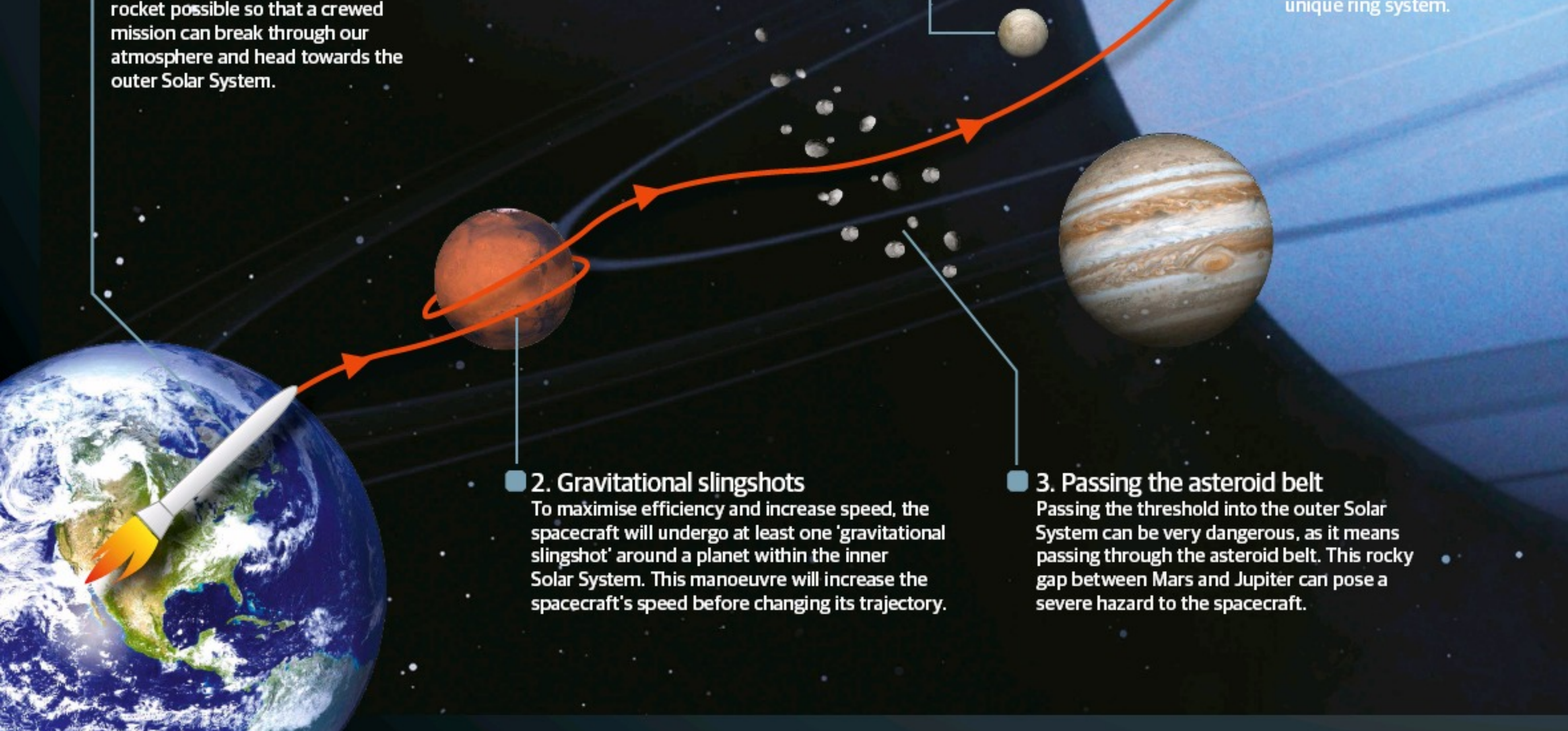
On 23 September 1846, the first planet in history was discovered using mathematics. French mathematician, Urbain Le Verrier, proposed there was a unknown object beyond Uranus that was affecting its orbit. So, Le Verrier calculated the unknown object's position, but unable to convince French astronomers, he sent his calculations to Johann Galle at the Berlin Observatory. Lo and behold, there was the eighth planet of the Solar System, Neptune.

Neptune is the most distant planet from the Sun, and it is over 30-times the distance of Earth from the Sun. This discovery completed the then quartet of gas giants, along with Jupiter, Saturn and Uranus. Although it is named after the Roman god of the sea, there is no such liquid water on this planet. Its composition is predominantly hydrogen (80 per cent), with the remainder being helium (19 per cent), methane (1.5 per cent) and traces of hydrogen deuteride and ethane.

This distant ice giant experiences some of the most intense, rough and rapid winds in the Solar System. Reaching speeds of up to 2,400 kilometres per hour (1,500 miles per hour), the winds of Neptune are vicious and, unfortunately, unexplainable. Winds occur on Earth as a result of the Sun's energy heating up different areas, causing temperature differences on the surface. As Neptune only receives 0.1 per cent of sunlight compared to the Earth, no one is sure what is the driving mechanism behind such an irregular windy powerhouse.

Only one spacecraft has ever ventured to The Blue Planet, and that was the historic Voyager 2 spacecraft. This was its final planetary stop after its 12 year journey of producing incredible images of our other planets, and before heading for interstellar space. Images taken in 1989 showed the glorious blue sphere dotted with darkened storms and white wisps of clouds at high altitudes.

How to get there



1. Setting sights for Neptune

As Neptune is the furthest planet from us, engineers and scientists must construct the most powerful rocket possible so that a crewed mission can break through our atmosphere and head towards the outer Solar System.

2. Gravitational slingshots

To maximise efficiency and increase speed, the spacecraft will undergo at least one 'gravitational slingshot' around a planet within the inner Solar System. This manoeuvre will increase the spacecraft's speed before changing its trajectory.

3. Passing the asteroid belt

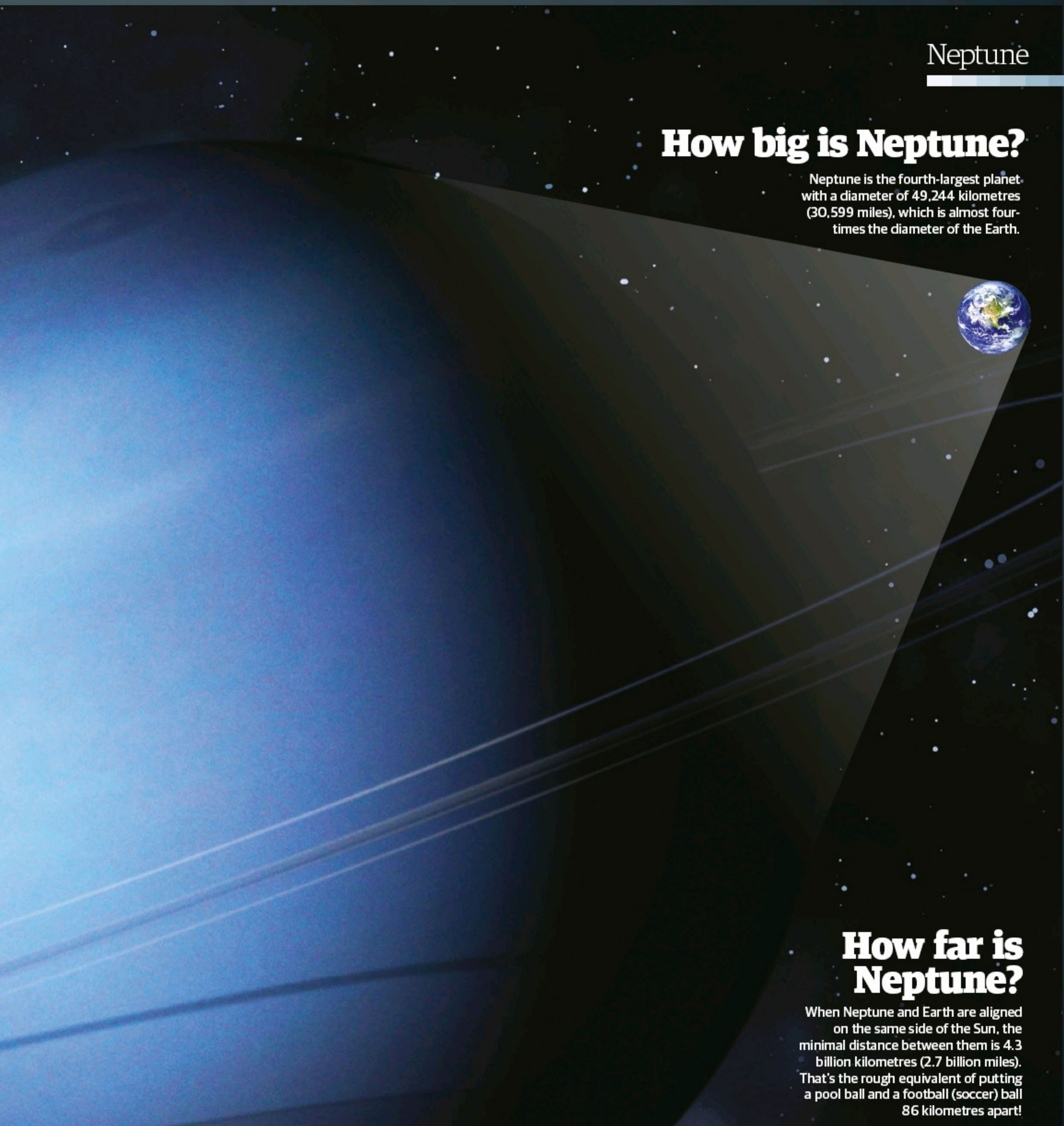
Passing the threshold into the outer Solar System can be very dangerous, as it means passing through the asteroid belt. This rocky gap between Mars and Jupiter can pose a severe hazard to the spacecraft.

4. Fuelling up at Europa

Every long journey needs a pit stop, and the untapped potential of complex chemistry and water ocean under the surface of Jupiter's moon Europa could provide valuable fuel.

5. Arriving at Neptune

After years of travelling at least 4.3 billion kilometres (2.7 billion miles) to your destination, you'll arrive at its 14 moons and its unique ring system.



How big is Neptune?

Neptune is the fourth-largest planet with a diameter of 49,244 kilometres (30,599 miles), which is almost four-times the diameter of the Earth.

How far is Neptune?

When Neptune and Earth are aligned on the same side of the Sun, the minimal distance between them is 4.3 billion kilometres (2.7 billion miles). That's the rough equivalent of putting a pool ball and a football (soccer) ball 86 kilometres apart!

© NASA/JPL; Science Photo Library - Mark Garlick

Top sights to see on Neptune

Although you can't literally step foot on Neptune because it is made primarily of gas, there are still some wonders to behold. Whether it's peering into its atmosphere and seeing the carnage that runs amuck, or seeing what objects have been caught in its powerful gravity, there is much to appreciate.

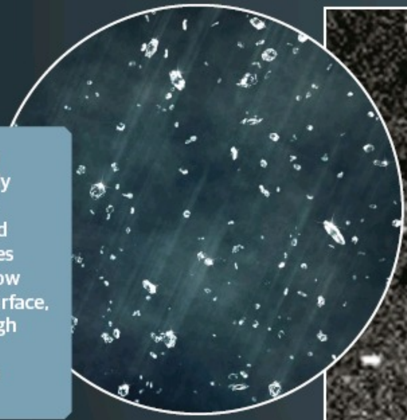
Before you reach the outer atmosphere, you'll first arrive at the planet's largest moon, Triton. The cold and icy moon presents a wonderful contrast of craters and a rugged cantaloupe terrain. This terrain indicates that there could be some form of geologic activity replenishing the surface. Does that mean there's a subsurface ocean? Scientists can neither confirm nor deny this, but a visit to the moon could prove revolutionary. As you get even closer to Neptune, the other 13 moons of the blue ice giant become more apparent, with their range of shapes and sizes.

But, moons aren't the only objects surrounding Neptune though: there are also six hidden planetary rings present. The main rings - named Galle, Le Verrier, Lassell, Arago and Adams - are all composed mainly of dust and small rocks. These are hard to decipher visibly as their composition, and the low levels of sunlight the area receives, causes them to have a poor reflectivity.

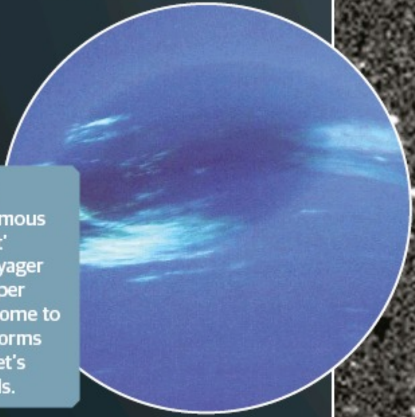
The cloud tops of Neptune have been studied extensively, and what has been seen since has brought many questions to the attention of astronomers. For instance, the baffling consequence of the rapid winds are the puzzling storms that arise within the planet's atmosphere.

The most famous storm is the 'Great Dark Spot', named for its resemblance to Jupiter's Great Red Spot. The Voyager 2 spacecraft imaged this anti-cyclonic storm, which was about the same size of Earth, in 1989. When the Hubble Space Telescope turned its sights to it five years later, the storm had disappeared. This created even more questions, such as how can such a massive surface feature vanish so quickly?

If, somehow, you could travel towards the core of the planet, around the 10,000 kilometre (6,214 mile) mark from the top of the atmosphere you might be able to see diamond rain. Scientists have theorised that the heat and pressure at this depth would condense and crush the methane in the atmosphere into tiny flecks of diamond.

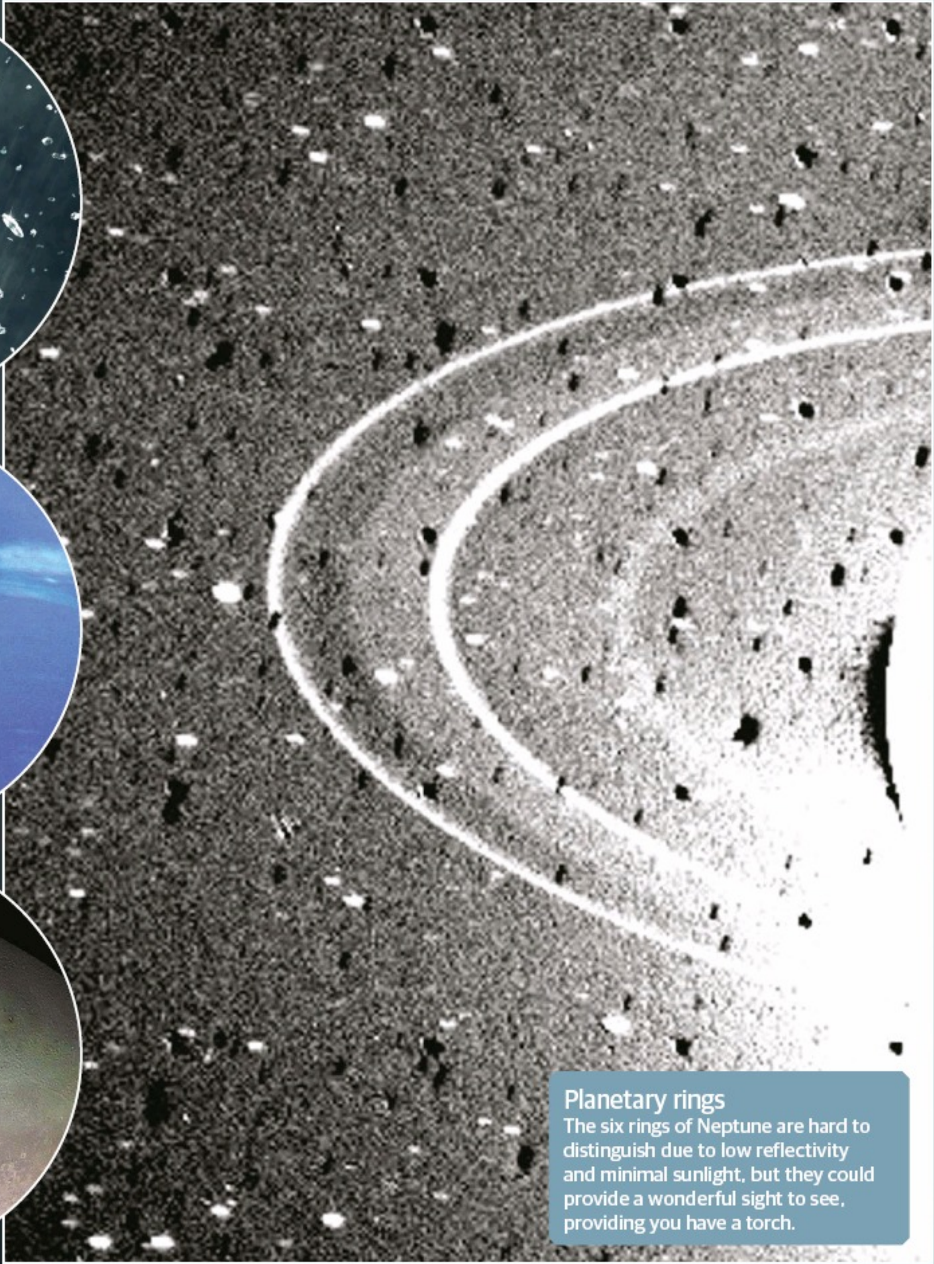


Diamond rain
Scientists recently theorised that at a depth of around 10,000 kilometres (6,214 miles) below the Neptunian surface, the extremely high pressure causes methane to form solid diamonds.



Dark storms
Much like the famous 'Great Dark Spot' observed by Voyager 2, Neptune's upper atmosphere is home to many intense storms amidst the planet's supersonic winds.

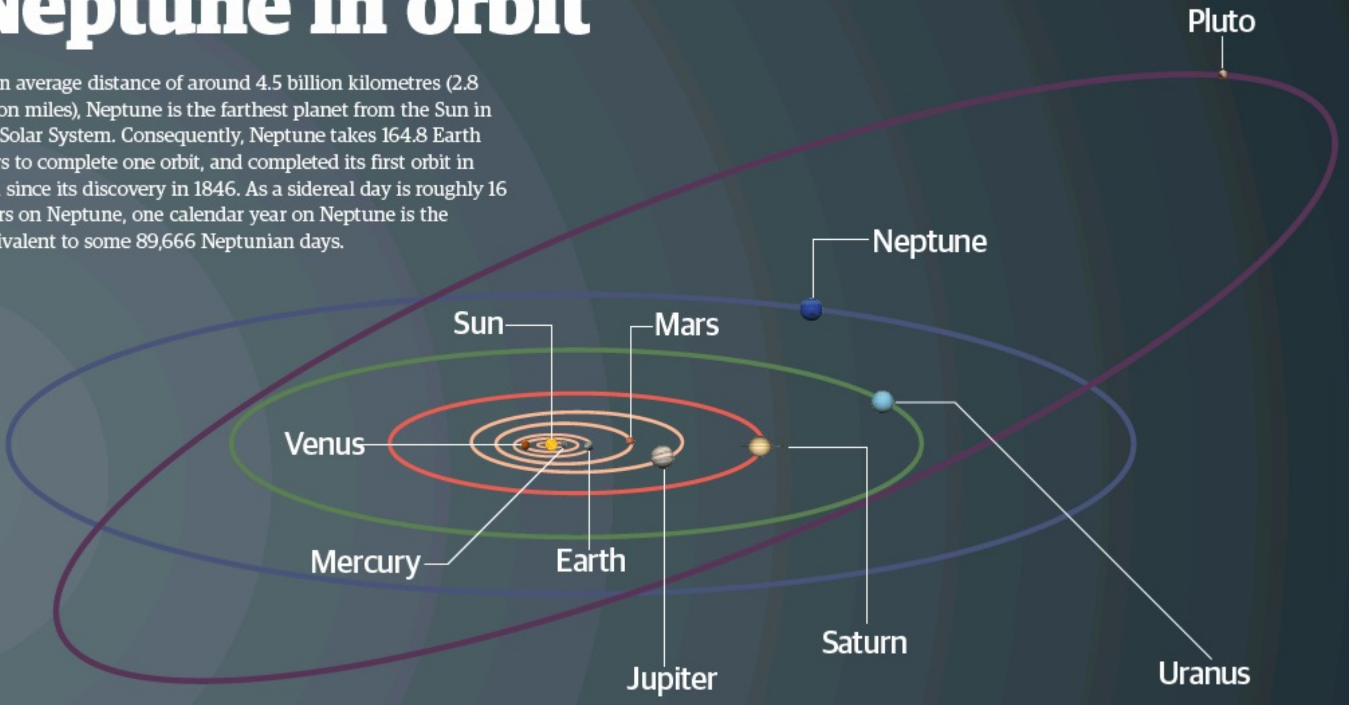
Neptunian moons
Neptune has 14 moons to choose from when it comes to lunar viewings, but the biggest and most interesting moon is Triton by far.



Planetary rings
The six rings of Neptune are hard to distinguish due to low reflectivity and minimal sunlight, but they could provide a wonderful sight to see, providing you have a torch.

Neptune in orbit

At an average distance of around 4.5 billion kilometres (2.8 billion miles), Neptune is the farthest planet from the Sun in our Solar System. Consequently, Neptune takes 164.8 Earth years to complete one orbit, and completed its first orbit in 2011 since its discovery in 1846. As a sidereal day is roughly 16 hours on Neptune, one calendar year on Neptune is the equivalent to some 89,666 Neptunian days.



Neptune in numbers

57x

The number of Earth's that could fit inside Neptune!

1989

Year of the first/last spacecraft flyby of Neptune

Neptune's weather

-214°C
-353°F

Neptune is one of the coldest planets in the Solar System with a temperature at -214 degrees Celsius (-353 degrees Fahrenheit) in the upper atmosphere. If you decide to go deeper into the planet, you'll need something stronger than an umbrella to shield yourself from the diamond rain.

1846

Year discovered by German astronomer, Johann Galle

16

Hours in a sidereal day on Neptune

80%

The hydrogen in Neptune's composition by volume

14

The number of Neptunian moons

4,498,396,441 km

The average distance between the Sun and Neptune

© NASA/JPL/USGS; Greg Stewart/Slac National Accelerator Laboratory;

The last time a human stepped on the Moon was the Apollo 17 mission in 1972

Our manned return to the Moon

What happens when the Space Station is decommissioned? **All About Space** asks ESA how the Deep Space Gateway, and how we could get humans back to the lunar surface

Interviewed by Lee Cavendish

Can you explain what the aims of the 'Deep Space Gateway' are?

The Deep Space Gateway is an initiative which is under discussion at the moment. It's in the early concept phases of how this thing will come together between the partners who have worked together on the International Space Station. That includes the European Space Agency, NASA, the Canadian Space Agency, the Japanese agency, JAXA and the Russian space agency, Roscosmos.

The idea is that as we look to move beyond low-Earth orbit, where we operate at the moment with the International Space Station, we would work together to build what we call the Deep Space Gateway. This would be a platform where humans could live and work that is in the vicinity of the Moon, so not on the lunar surface, but in orbit around the Moon.

This is a place where we would learn what it would mean to live and work away from the Earth. We would test technologies and do research as it becomes the first element in an infrastructure to allow exploration to the surface of the Moon, onwards to Mars and maybe to other destinations in the future. So it's really the first step in a sustainable architecture for exploration for humans.

Recently, there was a meeting in the Netherlands for discussing the science plans that would be involved in this project. What were some of the major talking points?

Yes, so we had this meeting at ESTEC, which is the European Space Research and Technology Centre in the Netherlands. We had around 200 people come to the meeting, and we were discussing how science could benefit from this platform if you were there. We talked about life science experiments. These could be things about learning the effects of the deep-space environment on human physiology, or understanding how life exposed to the environment of deep space can survive or can change to help us understand better how life has existed and emerged in different environments, or even how it could possibly move around the Solar System.

We found that we should be looking at the environment it effects. [For example] looking at the interaction between the Sun, the magnetic field from the Sun, the plasma from the Sun, the way that it interacts with the Moon and the Earth's system and the Earth's magnetosphere.

We had people wanting to talk about dust particles that move through the Solar System and interstellar dust grains that move through the Solar System that come from other places outside of our own Solar System, swept up as it moves through the galaxy.

There was a lot of interest in things that could be done at the lunar surface in a way that we could really explore the Moon in new ways, in new places, and ask ourselves new scientific questions. That would be enabled by surface missions controlled from the Deep Space Gateway, and the return of samples that would come from the surface of the Moon back to the Gateway and then returned [to Earth] with the astronauts from there.

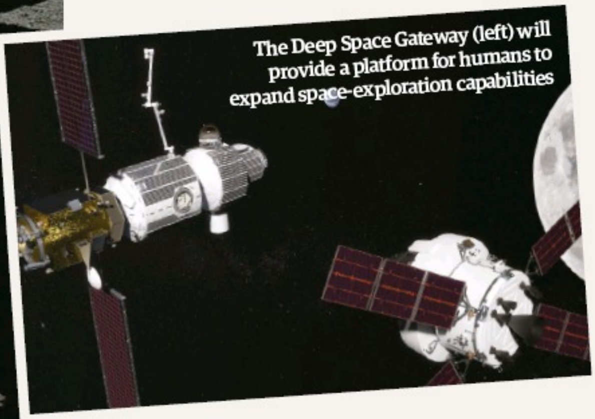
There could be the opportunity to make fundamental physics measurements and make astronomic observations as well. So there were really a lot of different ideas across a whole diverse range of subjects including life sciences, astronomy, physics, planetary sciences, all the system sciences and all sorts of things.

INTERVIEW BIO

James Carpenter

Dr James Carpenter is the human and robotic exploration strategy officer at the European Space Agency (ESA), based in Noordwijk, Netherlands. After gaining his PhD in Space and Planetary Science and Technology from the University of Leicester, Carpenter has worked for ESA since 2008. His responsibilities include handling, or generally being involved in, many ESA space exploration missions. This also involves interacting with many international and private organisations. Carpenter recently had to double the capacity for a meeting in the Netherlands regarding the Deep Space Gateway due to such a high demand of interest in the subject.

> "We could really explore the Moon in new ways, and ask ourselves new scientific questions"



The Deep Space Gateway (left) will provide a platform for humans to expand space-exploration capabilities

© NASA

Utilising a lunar base would allow us to fully analyse the surface of the Moon

Building and supporting the ISS has been an international effort for decades

"The lunar surface is the next destination for human exploration for ESA, after low Earth orbit where we live and work today"

On the subject of lunar missions. How could the project help us put humans back on the surface of the Moon?

So the lunar surface is the next destination for human exploration for ESA, after low-Earth orbit where we live and work today.

The idea is that the Deep Space Gateway can be a step forward in the architecture to get back to the lunar surface in a sustainable way. The Deep Space Gateway could act as a staging post in the lunar vicinity, so you could travel from Earth to the gateway, and then from the gateway down to the lunar surface and back again. It becomes sort of like a spaceport in that sense.

It's somewhere where you could have different countries using this as a common staging post, or a common spaceport, to get down to the lunar surface and back again. That's an idea that's some way off though; maybe right into the 2030's time frame we could be looking at something like that.

But, in the meantime, we will be looking to build the infrastructure and would try to use this to learn, to do research, to learn what it means to work and operate in deep space. At the same time, [we could] perhaps do some robotic precursor missions to prepare for these human missions, which should be able to come later.

There's been some talk of constructing a lunar base. Has there been an update on this scenario?

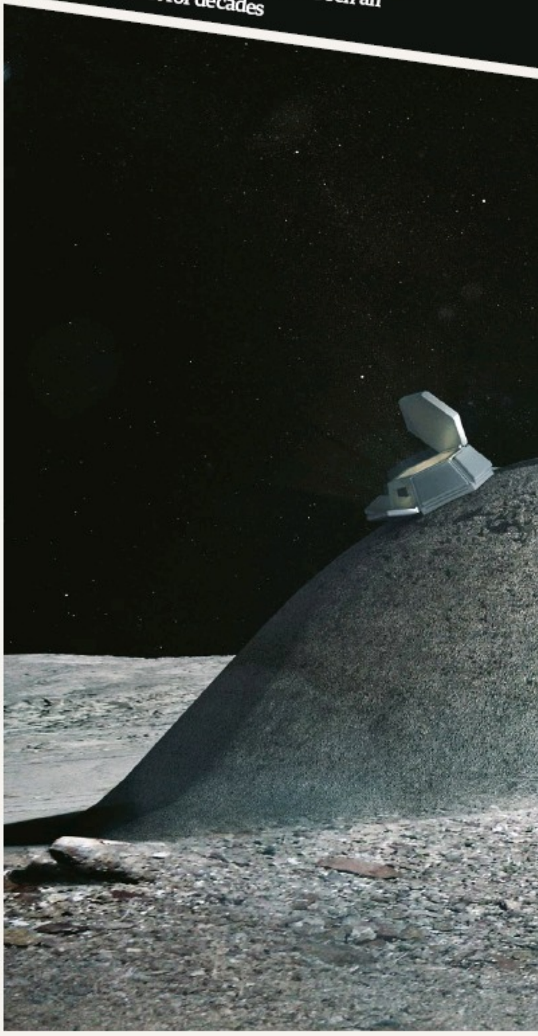
I know certainly that there is the idea of a lunar research station, lunar base or 'Moon Village'. It's an idea that has been around for a long time, but it is being talked about more and more as a vision for lunar exploration. While I don't think that anyone is committed today to achieving that, I think it can provide a guiding vision for some of the things that we do as we look to bring humans back to the lunar surface, and certainly the things that were doing.

The technologies, capabilities and the Deep Space Gateway can be an entry point to enable that, and can do so in a really international and active way.

What does the Moon have to offer that we haven't already analysed from the previous Apollo missions?

Apollo was outstanding and extraordinary as it transformed our understanding of planets, their formation, their evolution, the history of the Solar System and the history of Earth. I mean it was really transformative.

Then after Apollo there was a period where not a lot happened on the Moon. More recently we've had a number of missions going back there and looking at it from orbit [around the Moon], and these have produced a wealth of new data that has really



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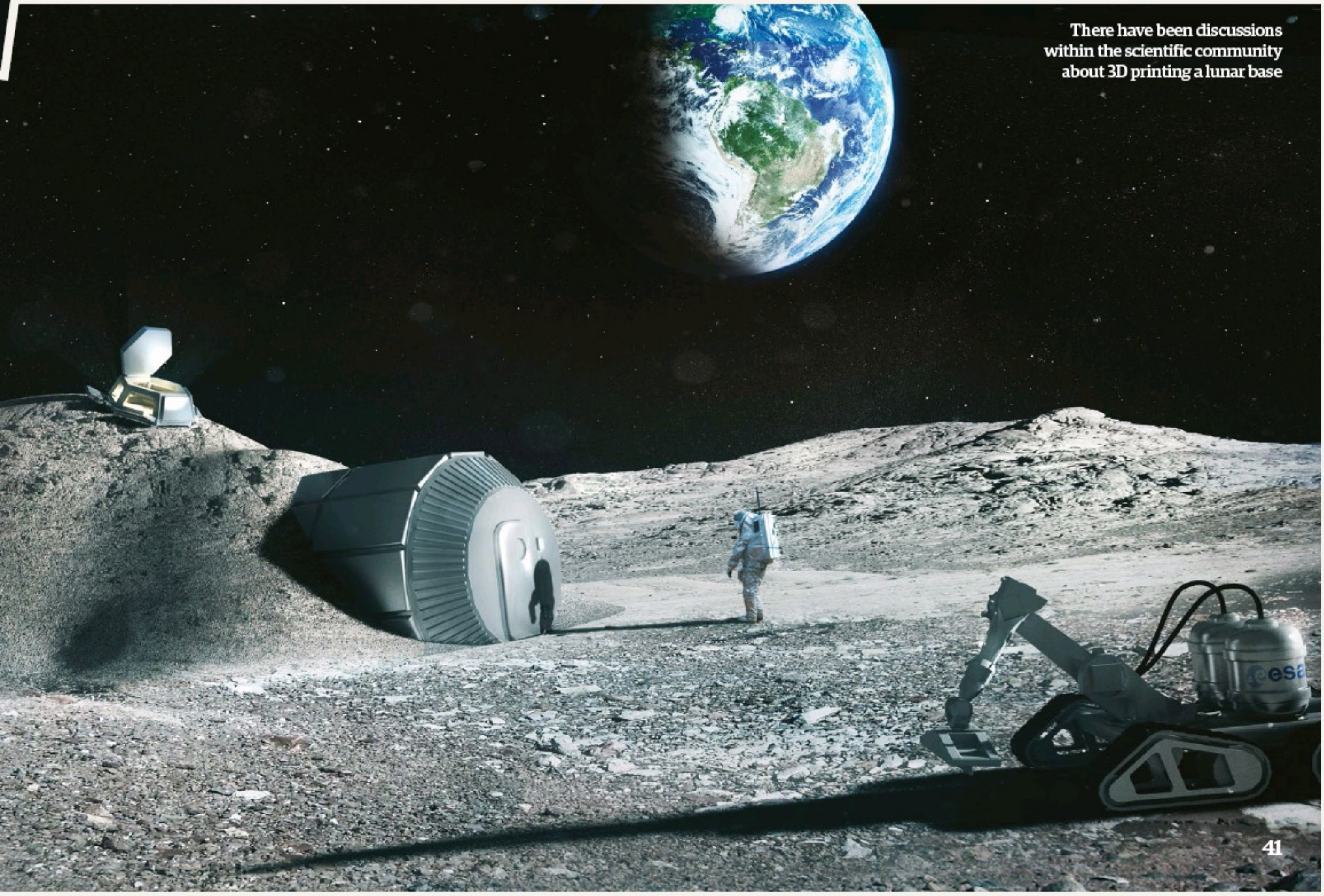
transformed our understanding.

They have shown us that the samples we did all this science with in the Apollo era, and continue to do science with now, are really only from a very small area. A very small region that isn't representative of the Moon as a whole, and that actually there is much more that we don't understand - [we realised] we've barely scratched the surface.

There have been some new and quite exciting results that have come in. Just in the last few years, my personal favourite has been the confirmation that we have frozen water ice, and other volatile chemistry, trapped at the lunar poles. These are permanently dark areas, which are some of the coldest places in the Solar System. This water ice and other chemistry we've found could give us some indication about where volatiles, water and life-enabling chemistry came from, how it got here. It could tell us something about some of the underlying chemistry that created the building blocks of life. But at the same time, water is hydrogen and oxygen, and those two things together are rocket fuel. So essentially, at the poles of the Moon, you have a huge deposit of rocket fuel that we could use in the future to move onwards into the Solar System.

There are new opportunities opening up. That is just one example which would require new missions to the [Moon's] surface to understand. We

Human exploration of the Solar System has been stale for many decades now, even since the last visit to our celestial neighbour



There have been discussions within the scientific community about 3D printing a lunar base

are starting to understand how little we know, and the massive potential that the Moon has to tell us about ourselves, about the context of all of us, about the history of the Solar System, the planets and where we're going next.

> "We are starting to understand how little we know, and the massive potential that the Moon has to tell us about ourselves"

What are the main challenges you are having to overcome for creating the Deep Space Gateway?
The work that's going on at the moment is the international partners working together to understand what the Deep Space Gateway would look like, discuss the different roles the partners would play and the different elements that they would prepare.

So say one agency may contribute a habitat, another agency [would contribute] the robotic parts and another agency something else. [At the moment], it's understanding, the same as with the International Space Station. It's really a partnership where everybody discusses what we want to get out of this, what do we want to bring, what are we going to contribute?

I think now is the time where we are working out, technically, what the thing looks like, what it needs to do, what the engineering side is. We need to talk to our partners internationally to define that and to define our roles.

We need to work with the stakeholders of the different agencies to identify how the thing will be supported [financially]. We also need to work with the science community, and other beneficiaries of the project, to make sure they're engaged and aware of the opportunity. When the opportunity has arisen we need to make sure that they're able to respond to the opportunity, with the intention that the Gateway would be put together in the lunar vicinity in the early parts of the next decade, not many years from now.

When you're on a mission like this, which is much further away from Earth than the International Space Station, there is going to be a lot risk. Say if there is a problem and you need to get the astronauts back to Earth safely, how would this be possible?
I think that these are all things that are built into the architecture's design to understand these kinds of considerations. So yes, that is certainly something that will be considered. But we also have to consider that we're used to working on the International Space Station. This is an extraordinary and quite huge infrastructure, which by the standards of any space-exploration endeavour is quite luxurious, and the Deep Space Gateway is not that.

The people who go to the Deep Space Gateway are really explorers going somewhere that no one has ever been before. I also think the risks are not the same as on the International Space Station, so we will work to mitigate them as best as we can. But this is really about exploration and going somewhere new.

What do you think needs to happen to turn this project into a firm reality?
At the moment there's the technical part, and there's the confirming that this is something that we will be investing in and spending money on. That's a question for the member states of ESA, and something ESA will discuss with its member states. Other agencies will need to work with their funding stakeholders to establish how this will be funded.

So these are decisions that, you would hope, will be made within the next couple of years. Then on the technical side, we have to do the work to define technically what this will look like, to create the design, the engineering requirements and to start putting it together.

ESA is now working with other industries in order to do just that on the European side, and similar efforts are going on elsewhere with other international partners.

ESA are also assessing lunar tools for future space exploration missions

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SPACE CHANGES HOW *YOU* THINK

Mind and body, humans are built for Earth. So what happens when we venture beyond our planet?

Written by Benjamin Skuse

Although fundamental to the existence of life on our world, the full force of gravity on the human body slowly wreaks havoc over a lifetime. As our bodies lose their youthful vigour, gravity compresses the spine, prolapses organs and prevents blood from freely flowing upwards, to cause varicose veins and swollen limbs.

But, without it, the story could be far worse. Living in a microgravity world on the International Space Station (ISS), astronauts' bodies begin to deteriorate in a way akin to rapid ageing. Not having to support the astronaut's weight in space, the body reacts the same way it does to a sedentary lifestyle: by releasing calcium normally stored in bone into the bloodstream, causing bone loss. Extended stays on Russia's former space station Mir resulted in bone mass loss of as much as 20 per cent. Similarly, with little need to contract muscles normally used to fight the force of gravity on Earth, astronauts can lose as much as 20 per cent muscle mass on spaceflights lasting just five to 11 days if they do not counter the effects with regular exercise.

While these effects on the body are significant, perhaps the most worrying upshot of living without gravity are the changes in the brain – sometimes permanently. More than half of astronauts have experienced symptoms of what is known as vision impairment and intracranial pressure (VIIP) during long missions.

Thought to be caused by the same liquid redistribution in the astronaut's bodies that gives them puffy faces, extra fluid in the skull is believed to increase pressure in the brain and the back of the eye. This can flatten the eyeball, which pushes the retina forward and inflames the optic nerve. The result is blurred sight, and effects can lead to long-term vision deterioration.

VIIP and other symptoms are concerning, but the ISS has little space to conduct full investigations,

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A photograph from the ISS shows stunning detail of much of the Atlantic coast of the United States, yet VIIP syndrome can make the view blurry for astronauts

so researchers have to be inventive back here on Earth. Alongside traditional animal studies and dry immersion in water, one of the more bizarre techniques involves asking volunteers to spend time in beds that are tilted so that their feet are higher than their heads. First devised by Soviet scientists in the early 1970s, the technique is said to have been invented to combat the sensation cosmonauts experienced of slipping off the foot of the bed on return to Earth.

Now, bed tilting is used by the likes of NASA to simulate bone loss and muscle wastage, as well as the shift of body fluids towards the head. Dr Donna Roberts from the Medical University of South Carolina leads a US team that aims to understand the changes to the brain astronauts experience in spaceflight. Roberts used the tilted bed technique to mimic microgravity, asking volunteers to spend up to 90 days in beds tilted 6 degrees.

While it may sound like a dream to some – watching movies, playing video games and even learning a foreign language from the comfort of a bed – participants were only allowed to lift their heads on one elbow to eat, had to use bedpans to void their bowels and took overhead showers while remaining in the head-down position.

Yet the volunteers' struggles were worth it. "I did MRI scans of their brain before and after bed rest," reveals Roberts. "When I looked at their scans I noticed that after bed rest there was crowding of brain tissue at the top of the brain."

> "Disturbances in the ability to carry out specific motor tasks have been found during spaceflight" **Dr Donna Roberts**

Aiming to corroborate her finding, Roberts then studied the brain MRI scans of NASA astronauts before and after spaceflight – one set who had taken short missions on the Space Shuttle and another who had stayed longer on the ISS. "I had two neuroradiologists have a look at the MRI scans, but I didn't tell them which group of astronauts the scans came from," she says. Strikingly, the neuroradiologists confirmed Roberts' suspicions, concluding that there was an upward shift of the brain and expansion of tissue along the top of the brain in all astronauts on longer missions, just like in the bed-rest volunteers.

What this means is still not fully understood, but Roberts suspects that it may ultimately result in a decrease in the outflow of cerebrospinal fluid and blood from the head, which in turn leads to intercranial pressure. This intercranial pressure is believed to cause the VIIP symptoms experienced by some astronauts.

Even more worryingly, the crowding of tissue along the top of the brain may affect how an astronaut senses their environment and their ability to interact with it. This area, known as the central sulcus, is so critical that neurosurgeons operating in this part of the brain often perform surgery while the patient is awake to avoid injury. "Disturbances in the ability to carry out specific motor tasks have been found during spaceflight," says Roberts. Although it is not certain that tissue crowding is the reason behind this, she warns that "any change to this region of the brain raises concerns".

Now, Roberts is collaborating with University of Florida investigator Professor Rachael Seidler to further understand the effects of space on the brain. Seidler conducted the first brain MRI scans on astronauts in a 2016 study to look at regional changes of grey matter distribution, with some parallel findings to those of Roberts. Importantly though, Seidler's study captured how the brain expands in regions that process information and control movement of the legs, suggesting that the MRIs showed the brain learning the new skill of moving in microgravity. "Because of microgravity, the sensory information astronauts are getting from the limbs is greatly reduced, so we think this is the brain's way of turning up the gain of the system," she says.

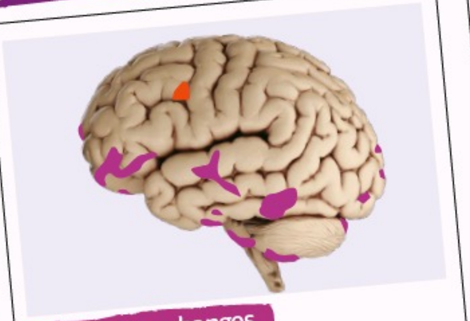
NASA astronaut Mae Jemison demonstrates weightlessness

A participant in Seidler's bed rest study at the University of Texas Medical Branch in Galveston

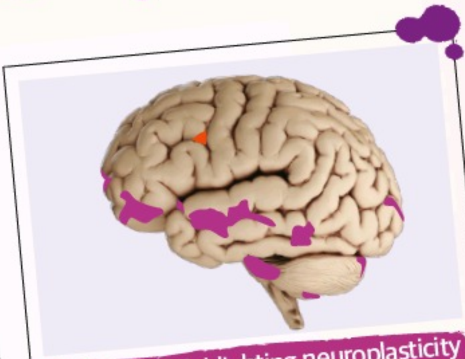
The two investigators are pooling their knowledge on a NASA-sponsored bed-rest study to evaluate any change in the blood flow to the brain and brain structure that might occur during bed rest, with the added complication of carbon dioxide exposure. "Experiments on Earth have shown that people get headaches or have a little cognitive fogginess in that kind of environment," explains Seidler. Subjects have been exposed to an atmosphere that has lower levels of CO_2 than typical carbon dioxide exposure studies, but slightly higher levels than are typically found on Earth – similar to the atmosphere experienced by astronauts on the ISS. "The levels on the ISS are much lower, but astronauts report the same symptoms as people taking part in CO_2 exposure studies, so the question is: is there something about the combination of increased fluid in the brain with elevated CO_2 that magnifies the effects?" Says Seidler. Having just finished collecting data, results will be coming soon.

Progress in understanding how the brain is affected by microgravity is also being made on the other side of the Atlantic. Angelique Van Ombergen, from the University of Antwerp, Belgium, works with Belgian and Russian colleagues in a project led by Floris Wuyts to try to understand the physiological changes taking place during spaceflight. With a willing male cosmonaut who had spent 169 days on the ISS

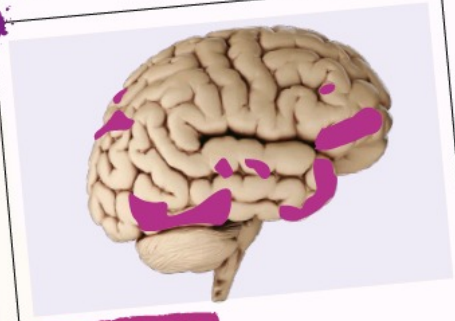
How microgravity affects your grey matter


Grey matter changes

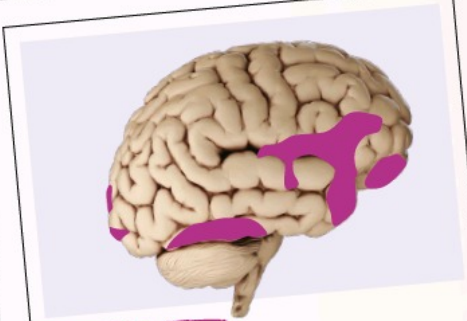
While orange marks show regions with significant grey matter volume increases, purple signifies significant grey matter decreases.


Spaceflight highlighting neuroplasticity

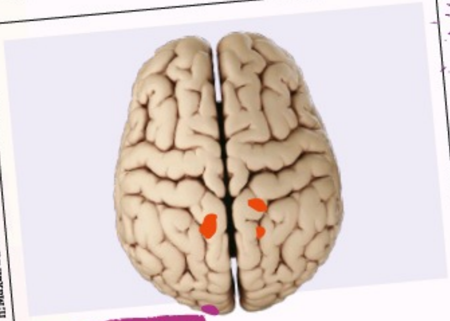
Increased grey matter concentration from before to after spaceflight, potentially reflecting different neuroplasticity processes.


Brain shifted up

Decreased grey matter concentration from before to after spaceflight, potentially reflecting an upward shift of the brain.


Brain shifted up

Decreased grey matter concentration in a different region from before to after spaceflight, potentially reflecting an upward shift.


Controlling legs

Increased concentration from before to after spaceflight in regions that process sensory input from, and control movement of the lower limbs.

Participants discuss readings of the parabolic flight Van Ombergen studied

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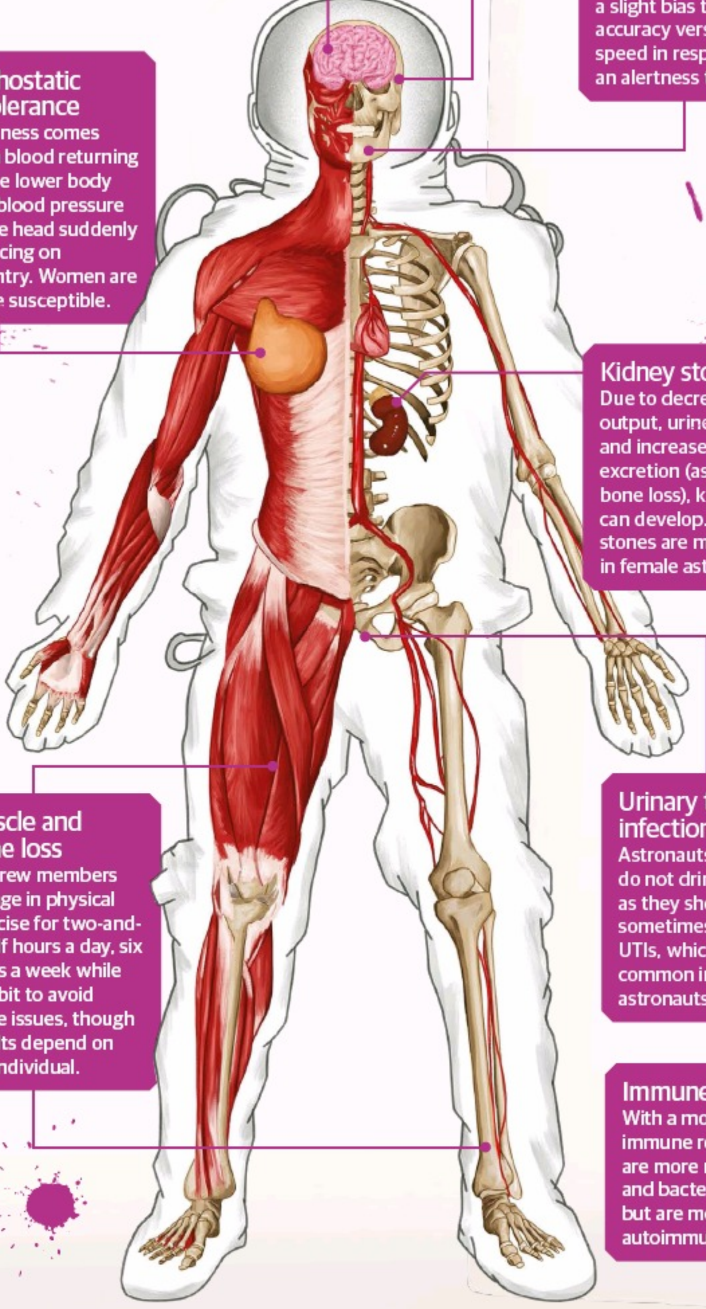
How would you be affected by space?

The body and mind can be affected in many ways

Female astronaut



VIIP syndrome
Although female astronauts have not shown significant visual impairment, that may be because so few women have been in space.

Hearing loss
While hearing sensitivity declines far slower in female astronauts with increasing age, there is no evidence to link this to microgravity exposure.

Accuracy versus speed
Women demonstrate a slight bias towards accuracy versus speed in response to an alertness test.

Orthostatic intolerance
Dizziness comes from blood returning to the lower body and blood pressure in the head suddenly reducing on re-entry. Women are more susceptible.

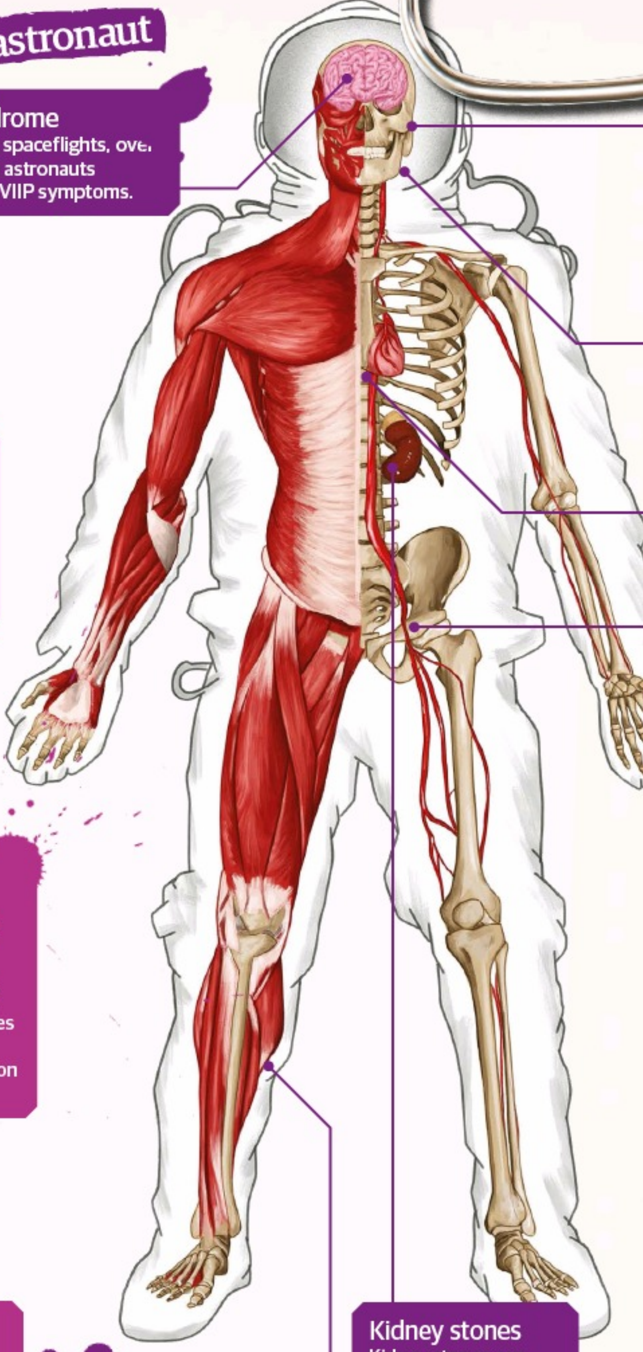
Kidney stones
Due to decreased urine output, urine acidity and increased calcium excretion (as a result of bone loss), kidney stones can develop. Struvite stones are more common in female astronauts.

Muscle and bone loss
ISS crew members engage in physical exercise for two-and-a-half hours a day, six times a week while in orbit to avoid these issues, though results depend on the individual.

Urinary tract infections
Astronauts probably do not drink as much as they should, sometimes leading to UTIs, which are more common in female astronauts.

Immune response
With a more potent immune response, women are more resistant to viral and bacterial infections, but are more susceptible to autoimmune diseases.

Male astronaut



VIIP syndrome
During long spaceflights, over half of male astronauts experience VIIP symptoms.

Immune response
With a weaker immune response, men are less resistant to viral and bacterial infections.

Kidney stones
Kidney stones can range from tiny microscopic crystals to stones as large as walnuts, and cause excruciating pain. Calcium oxalate stones are more prevalent in men.

Muscle and bone loss
After six months in space, an astronaut's osteoporosis symptoms can be compared to those in elderly women on Earth, though there is large individual variability.

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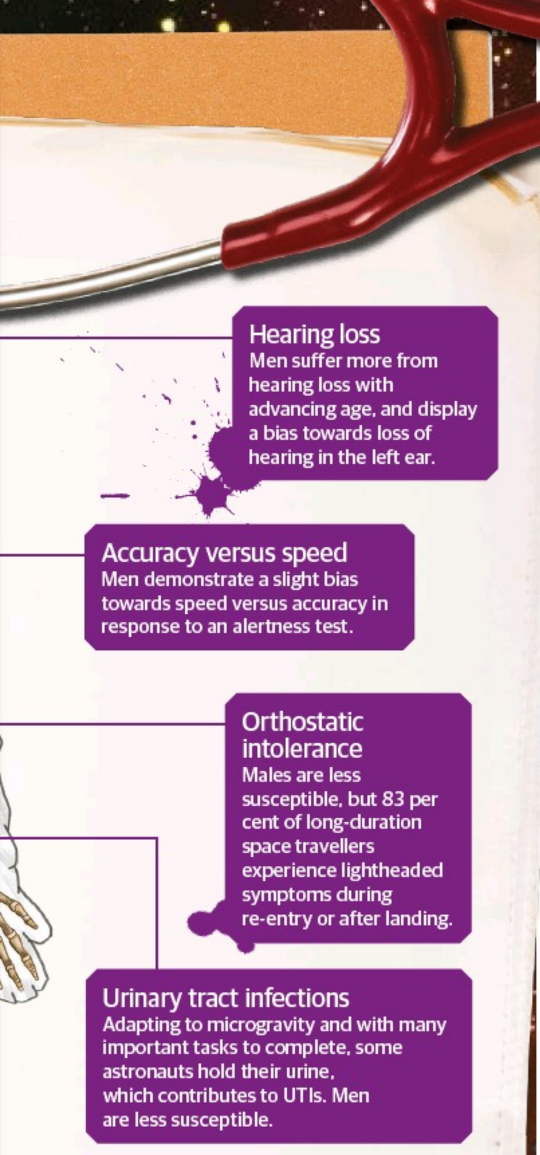


Hearing loss
Men suffer more from hearing loss with advancing age, and display a bias towards loss of hearing in the left ear.

Accuracy versus speed
Men demonstrate a slight bias towards speed versus accuracy in response to an alertness test.

Orthostatic intolerance
Males are less susceptible, but 83 per cent of long-duration space travellers experience lightheaded symptoms during re-entry or after landing.

Urinary tract infections
Adapting to microgravity and with many important tasks to complete, some astronauts hold their urine, which contributes to UTIs. Men are less susceptible.

Counteracting the effect

Cosmic rays

Enhanced shielding would certainly help, so building Mars-bound spacecraft in space could be an option to allow well-shielded vehicles too heavy to lift off from Earth to be assembled. Meanwhile, cosmic-ray fighting drugs, preventive medical treatments, enhanced foods and special exercise regimes are promising to help the body repair damage.

If damage has already affected an astronaut's performance, intelligent systems could take over critical decision making – but hopefully not with the catastrophic outcome wrought by the sentient computer HAL 9000 in *2001: A Space Odyssey*.

Microgravity

Artificial gravity, as envisioned aboard Discovery One in the classic film *2001: A Space Odyssey*, might counteract the brain changes caused by microgravity.

If this proves impossible though, astronauts could simply rehearse various actions in their mind (called mental imagery) which has been shown to improve sensorimotor performance, muscular force and preparation for the sudden absence of gravity after launch.

happy to have his brain analysed, they found that the brain's cortex reorganises itself to adapt to the challenges of a long-duration spaceflight. Noting less connectivity strength in certain brain areas, the team is looking to confirm if these changes cause temporary movement issues - like difficulties with walking, gait and posture - and balance problems - like dizziness, vertigo and nausea - astronauts experience when returning to Earth.

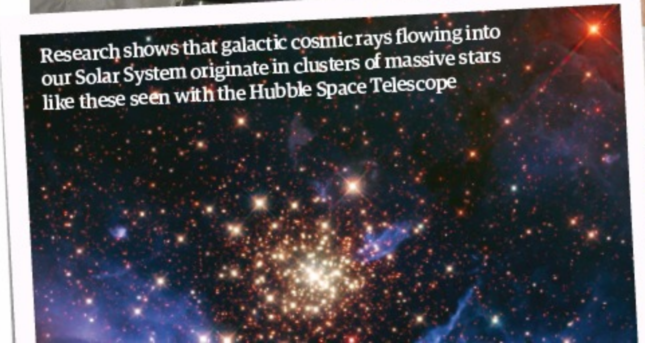
Taking a different tack, this year the team reported findings from a study in which volunteers had an MRI before and after a parabolic flight. Jokingly known as a 'vomit comet', parabolic flight involves an aircraft following a trajectory in which a steep climb precedes a 20-second levelling out period, during which the acceleration of the aircraft cancels out the acceleration of gravity - resembling zero gravity. A steep descent then takes the aircraft back to its initial altitude, ready to restart. Normally used by astronauts to prepare for the sudden absence of gravity after launch, in Van Ombergen's study 28 participants were loaded in an Airbus A-300 Zero G aircraft, and were then subjected to 31 parabolic flight manoeuvres over the course of approximately three hours.

Interestingly, although warning that there are some crucial differences between parabolic flight and spaceflight, Van Ombergen says the study shows that even short-duration microgravity exposure or gravitational alterations induce changes in a brain region specifically involved in multisensory integration and spatial tasks. In other words, this brain change led participants to experience symptoms of dizziness and disequilibrium similar to people here on Earth with a central vestibular disorder.

It is well known that space motion sickness and spatial disorientation is experienced by 60 to 80 per cent of astronaunts during the first couple of days in space, but understanding how and why it happens

> "Even short-duration microgravity exposure or gravitational alterations induce changes in the brain"

NASA astronaut Dan Burbank during his six-day-a-week, two-and-a-half-hour exercise programme



Research shows that galactic cosmic rays flowing into our Solar System originate in clusters of massive stars like these seen with the Hubble Space Telescope

Symptoms

How can microgravity change you?

Blurred vision
Fluid not flowing out of the brain increases pressure to the back of the eye, flattening the eyeball, pushing the retina forward and inflaming the optic nerve.

Weak motor and multi-tasking skills
Crowding of tissue in the frontal and parietal lobes may be behind poorer motor task performance during spaceflight, particularly while astronauts simultaneously engage in secondary cognitive tasks.

Movement and balance back on Earth
Reduced connectivity between the motor cortex and cerebellum could be causing the temporary movement and balance problems astronauts experience upon return to Earth.

Space motion sickness
This syndrome may come from changes to a region of the brain that processes balance, body position and visual input, and how we perceive what is up and down.

Death by cosmic rays?
Damaging delicate neuronal structure, cosmic rays have the potential to compromise an astronaut's ability to make critical decisions on a deep-space mission, with calamitous consequences.

Death by CO_2?
Similar to the effects of cosmic rays, some reports show negative consequences in terms of sleep, cognition and psychomotor performance from elevated carbon dioxide levels.

Chris Cassidy of NASA is too weak to walk shortly after he landed at the end of a five-and-a-half-month mission

© NASA

> "Space tourism and long stays on the ISS are not the only trips space administrations need to prepare for"

is important, particularly when large groups of untrained tourists begin launching into space. Just as vigorous exercise combats muscle wastage in astronauts, Van Ombergen's work is a step towards developing countermeasures to help astronauts and space tourists cope with gravity transitions too.

Of course, space tourism and long stays on the ISS are not the only trips space administrations need to prepare for. With expeditions and even eventual colonisation of the Moon and Mars planned for the coming decades, astronauts' bodies will have to contend with much more than the effects of microgravity. This is because, for the first time, they will be dealing with long-term exposure to cosmic radiation. "Radiation on Earth is what we call sparsely ionising, while galactic cosmic rays are densely ionising," explains Charles Limoli from the University of California, Irvine. "When these densely ionising rays travel through the body, they leave behind a track of damage that the body's cells find very difficult to repair."

Consisting of anything from hydrogen nuclei all the way up on the Periodic Table to lead, galactic cosmic rays consist of atoms stripped of their electrons speeding through the galaxy at near the speed of light. When they pass through the body they cause molecules in living tissue to break apart. "Then, travelling perpendicular from the track are what we call delta rays," adds Limoli. "These are more sparsely ionising radiation tracks that can emanate away from the primary track - imagine a one centimetre cylinder of potential cellular damage for every heavy particle passing through your body."

"Even on the ISS, astronauts report seeing flashes of light, which are pieces of galactic cosmic radiation that are passing though and stimulating the optic nerve," reveals Thomas Williams, a scientist at NASA's directorate for Human Health & Performance.

The effects of these rays are unclear, but Limoli is conducting rodent experiments here on Earth to find out how they might affect the brain, and his results paint a bleak picture. After being exposed to low dose of highly ionising radiation, rodents became far less able to perform behavioural tasks, such as being able to tell a new object from a familiar one. Most worryingly, the rodents did not recover - even after a year. Analysis of the rodent's brains highlighted the problem. The radiation caused persistent neuroinflammation, lasting for more than six months and irrevocably damaged the integrity of the rodent's neural circuits.

On a Mars mission, this kind of damage could impair memory, learning, planning, focus and multi-tasking skills, all while simultaneously increasing the fear response and anxiety. Considering Mars astronauts will undoubtedly be required to make mission-critical decisions quickly, none of this bodes well for future explorations.

Because of this, work is already underway to counteract the potential damage from cosmic rays. "Biological countermeasures targeted against oxidative and inflammatory pathways, advanced shielding methodologies implementing new materials and even utilising specially designed helmets to protect the brain are all being pursued," remarks Limoli, who is himself deeply involved in designing top-secret cosmic-ray-fighting drugs.

"One area we're looking at is preventive medical treatment based on really interesting studies on helping to prevent the damage from radiation treatment back here on Earth," adds Williams. "Bionutrients is another fascinating area - how do we harness what nature presents to us to help protect our crews against the effects of radiation?"

Limoli concludes: "We need to protect these people, not only for a mission to Mars, but for future missions over the coming millennia."

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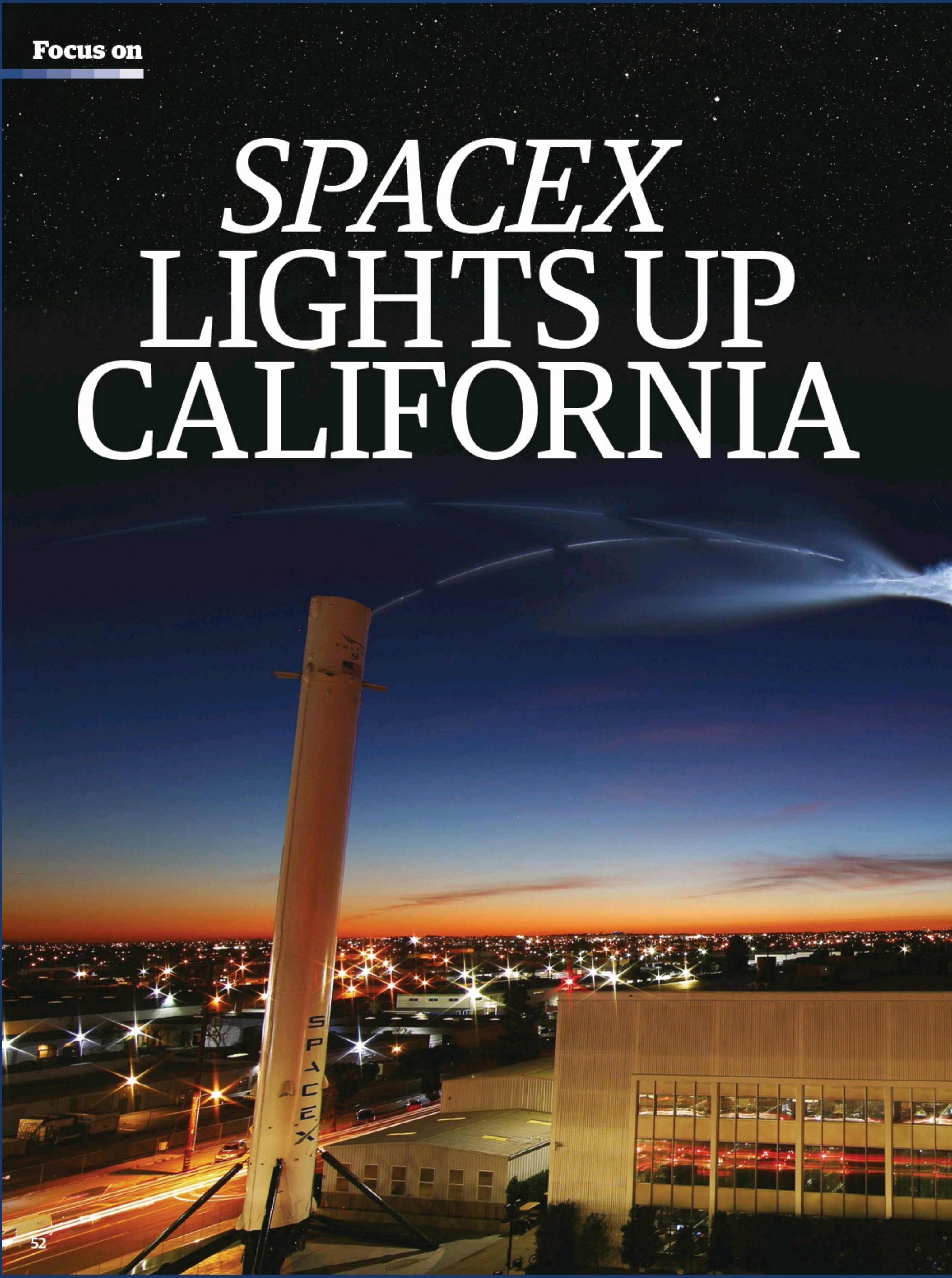
SPACEX LIGHTS UP CALIFORNIA



What many citizens believed was a UFO sighting was actually Elon Musk's private space company launching their last rocket of 2017

On 22 December 2017, SpaceX gave their own marvellous light show in the skies over south California, with many taking to the streets to witness the launch of the private space company's Falcon 9. Although it was nothing more than the powerful rocket giving off unusual exhaust plumes, on its mission to carry ten satellites for Iridium Communications into space, some unknowing residents thought the illuminating stream was something more extraterrestrial.

SpaceX launched its Falcon 9 rocket from the Vandenberg Air Force Base and, what people immediately began to notice, was a white streak of light piercing the night sky, which was shortly followed by an expansion of vapour that resembled a very strange 'fish-like' shape.

This is an unusual occurrence, but it was nothing mysterious or unearthly. It can easily be explained by the rocket's incredibly high altitude, according to the viewers' perspective at ground level. As the Sun had recently set, it wasn't far below the horizon, but it was still hidden from the observers on the surface. As the rocket reached higher altitudes, it moved into the line of light thrown out by our nearest star. The sunlight bounced off the clouds of frozen water crystals, creating the magnificent view that caused much entertainment and speculation.

A flurry of social media activity arose from watching this spectacle. The Los Angeles Fire Department put out an online statement confirming that this 'mysterious light in the sky' was just a rocket, which was putting satellites into low-Earth orbit. This brought the talk of it being a UFO to an abrupt end.

The launch was an overall success. All ten of Iridium's satellites were deployed in space, contributing to one of the largest tech upgrades in history. This is the fourth time ten satellites have been launched at once, as SpaceX assists Iridium with forming a next-generation global satellite constellation known as Iridium NEXT.

As SpaceX are contracted to place 75 satellites in this constellation, many more of these launches are expected to happen before concluding around mid-2018. The launch brought a fruitful year for SpaceX to a close, giving Elon Musk's company a positive outlook for 2018.

The launch marked SpaceX's 18th mission of 2017 and their fourth for company Iridium Communications

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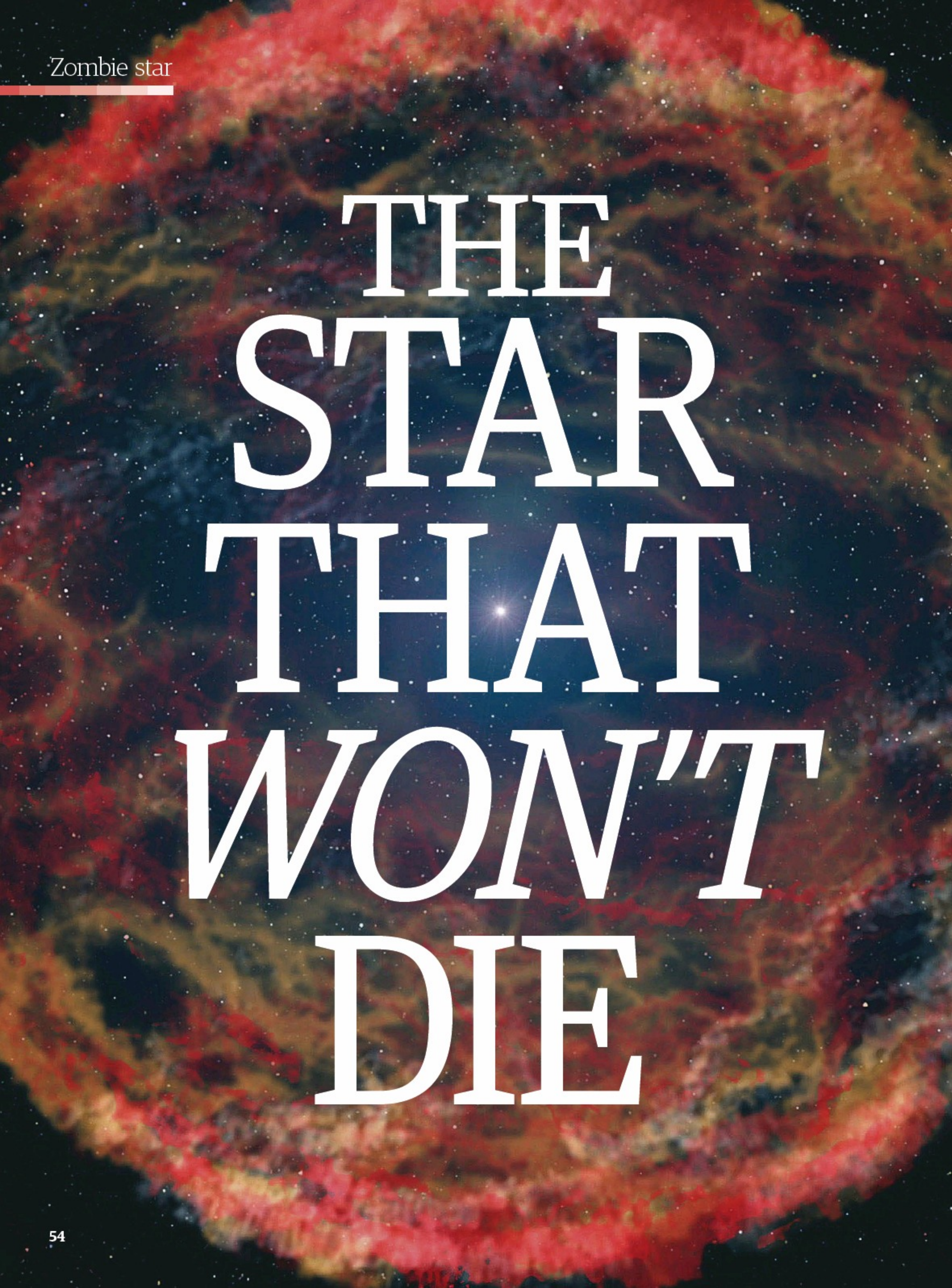

THE STAR THAT *WON'T* DIE

Astronomers have encountered a star that continues to resurrect itself. But how is it coming back to life? **All About Space** meets the team with some head-turning answers

Written by Lee Cavendish

Much like us humans, stars have a birth, a life and eventually, a dramatic end. Stars have a much more prolonged lifetime though, ranging from a few million years to trillions of years. The death of a star is dependant on its mass: it can either gently void its outer layers to form a planetary nebula or blow itself apart in a magnificent explosion called a supernova. For a regular star, a supernova is a one-off event, marking the end of a star's proactive life – or, at least that's what we thought.

Astronomers have found a star that has appeared to go through multiple supernovae in a space of over 60 years. This astronomical enigma challenges our understanding of supernovae, and the nature of massive stars. There are two common types of supernova: Type Ia and Type II supernova. Firstly, a Type Ia supernova commonly occurs in a pair of stars gravitationally bound together, known in astronomy as a binary star system. In this case, one of the stars must be a white dwarf star – a very dense and small stellar core remnant – and its companion can either be a giant star or an even smaller white dwarf. As the stellar dwarf begins to consume the contents of its partner, it will eventually reach 1.4-times the mass of our Sun, known as the Chandrasekhar Limit. This forces the white dwarf into a state of instability, thus dying in an extravagant, bright explosion known as a Type Ia supernova.

A supernova doesn't just occur in a white dwarf binary star system though. It can also occur to some of the most massive lone stars in the universe with masses of at least eight-times our Sun's. When these stars reach the end of their life, the hydrogen and eventually helium, powering the star's core will begin to be converted into higher-mass elements in order to keep its engine running. From helium, carbon is made, then oxygen, then neon, then magnesium, then silicon, until iron is produced in its core. At this point, the star requires energy to convert iron into a heavier element, rather than radiate energy. This is the final hurrah for the star, as it can no longer produce sufficient energy to counteract the cooling core and it eventually collapses under its own mass. This causes an implosion within the star, which bounces off the iron core and disperses its outer layers. This event is referred to as a Type II supernova; it sends copious amounts of gas into the cosmos, where it is recycled for future stars, planets and anything else which may lie out there.

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> "This discovery has made astronomers question the very nature of supernovae and consider new explanations"

Iair Arcavi, an astronomer at Las Cumbres Observatory, led the discovery of the unusual star

These two types of supernovae would appear indistinguishable to the naked eye, as they'd just appear to be spectacular explosions that scatter gas and dust throughout the universe. However, there are subtle differences between the two types that are revealed by the supernova's spectrum, which shows the intensity of light across a range of wavelengths. When an element is present in the gas and dust, it will absorb energy at a specific wavelength, and astronomers can identify this by studying the chemical fingerprint that is its spectrum.

There is also the characterisation of its brightness fading over time. When the commencing explosion lights up the sky, astronomers worldwide turn their telescopes to the scene of the crime to observe the afterglow. Astronomers construct a graph to see how the brightness of the star changes over an extended period of time, also known as a lightcurve. It is the shape of the lightcurve that helps astronomers determine what type of supernova occurred.

If you're looking at the lightcurve of a Type Ia supernova, the two most distinguishable features are the sharp increase in brightness, reaching up to five-billion-times the luminosity of our Sun, followed by a gradual decline. When compared to the lightcurve of a Type II supernova, the Type II has a similar sharp initial increase in brightness, but there tends to be a period of no luminosity change after its explosion, followed by a dimming lasting approximately 100 days. When comparing the spectra of the two supernovae there is actually just one simple question to ask when differentiating the two: are there hydrogen absorption lines? If the answer is yes, then you have a Type II supernova. If they are not present, you have a Type Ia supernova.

In February 2013, the California Institute of Technology (Caltech)-led intermediate Palomar Transient Factory (iPTF) project started its search for supernovae, among other transient objects, exploding in the night sky from the Palomar Observatory in San Diego, California, US. "iPTF was very successful in finding supernova – so successful, in fact, that it was finding about ten supernovae every night," Iair Arcavi, NASA Einstein Fellow at the University of California, Santa Barbara and formerly of the Las Cumbres Observatory Global Telescope (LCOGT), tells All About Space. "This is more than we can follow, so we had to choose which ones we thought were interesting and which ones we let go."

Then, in September 2014, the project identified one supernova that originally didn't provoke much of a reaction. "iPTF14hls was one of those we initially let go because when it was discovered, it was getting faint. So we thought it was just an old supernova [that had] passed its peak luminosity," continues Arcavi. "However, iPTF continued to image that part of the sky for its survey, so we were able to see what iPTF14hls was doing for the next few months.

"In February [2015], an intern working for me, Zheng (Andrew) Wong, noticed that iPTF14hls started to get bright again. He asked me whether that was normal, and I said absolutely not, a supernova almost never gets brighter again after having faded." What the LCOGT team had originally classified as a Type II-P supernova, based on its spectra and the plateau in its lightcurve, seemed to be coming back to life.

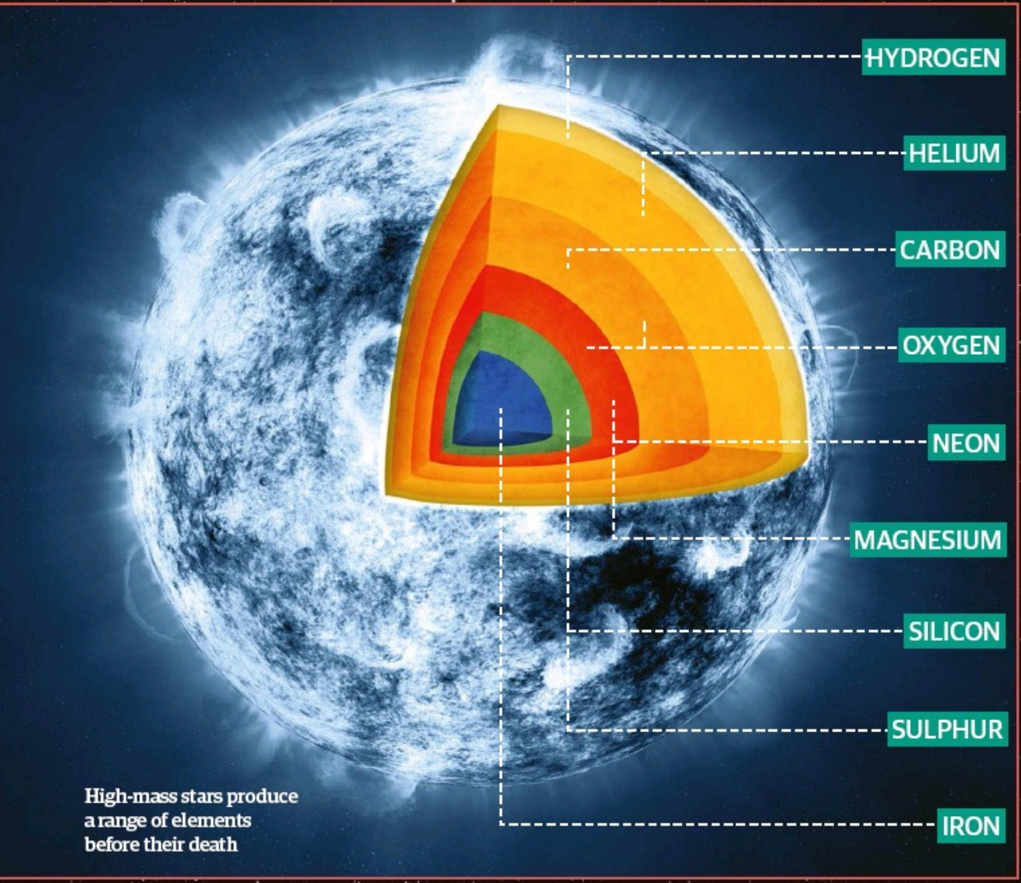
This 'zombie star' iPTF14hls, located over half-a-billion-light-years away in the constellation of Ursa Major (The Great Bear), proved to be quite the conundrum across the scientific community. This mysterious stellar phenomenon surpassed the typical 100-day lightcurve; instead it displayed an astonishing five peaks over the next 600 days under around-the-clock observations, and also appears to age ten-times slower than expected. This discovery has made astronomers question the very nature of supernovae and consider new explanations for such an event. Andy Howell, leader of the supernova team at LCOGT, described iPTF14hls as "a problem for our standard theories of supernovae. When that happens, it forces us to get creative." This called for further investigation, along with much creativity.

Unfortunately, astronomers couldn't pin down a proper explanation for such an event. If a theory was suggested to explain its erratic behaviour, there was always a new piece of data ready to disprove it. "With each new piece of data we got, the supernova kept getting weirder and weirder," Howell explains. "We initially had some theories that we thought could explain the data, but then we'd get new data that would refute those theories."

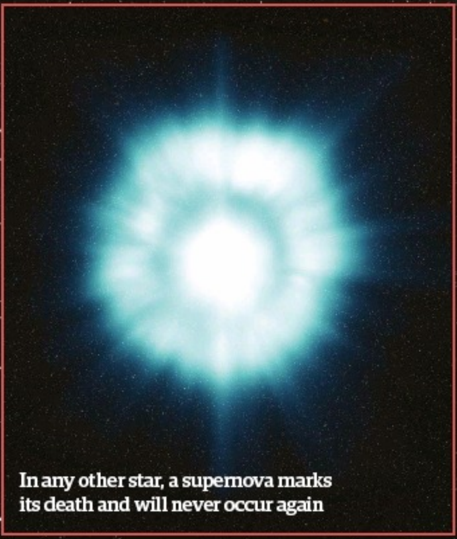
To make matters even more interesting, the researchers that were already working hard to decipher what they could from the observations of the perpetual star delved deeper into the archives. As it turns out, there was a recorded explosion at the exact same position in 1954. Although there is still some doubt whether this is the case, there is an extremely strong likelihood that it is the same star. Therefore, this star has been producing explosion after explosion for over 60 years – and has miraculously survived each time.

To power such an ancient engine, there's got to be a lot of fuel in the tank, thus expelling copious amounts of hydrogen in the process. Arcavi, Howell and their colleagues have estimated that hydrogen gas roughly 50-times the mass of the Sun has been ejected from the star alone. With this level of mass being thrown out into the cosmos, the original mass of iPTF14hls would have been enormous. Because of this, Arcavi again estimates that this star would have been at least 100-times the mass of our Sun.

> "With each new piece of data we got, the supernova kept getting weirder and weirder" **Andy Howell**



High-mass stars produce a range of elements before their death



In any other star, a supernova marks its death and will never occur again

The universe's exploding stars

There are two common types of supernovae: Type Ia and II. However, iPTF14hls seems to defy our understanding of supernovae, so astronomers have had to come up with a new explanation

Type Ia supernova

Fuelling the supernova
Here, the red supergiant swells due to increased radiation pressure, the white dwarf begins to consume its companion's outer layers.

Increasing instability
The white dwarf will continue to strip the material off the red supergiant, becoming more and more unstable as it does.

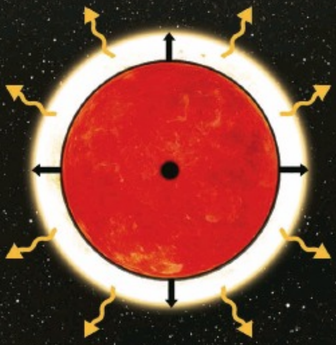
The grand finale
When the white dwarf reaches 1.4-times the mass of the Sun, it reaches the point of no return and explodes as a Type Ia supernova.

Type II supernova

Creating the medley of metals
The massive star will create layers of heavier elements in the core, until it reaches iron. This will spark the beginning of the end.

Star out of equilibrium
As the core can no longer produce sufficient energy to balance out the gravitational pressure of the star's own mass, it is essentially doomed.

Crushing under force
The gravity of the star crushes and condenses the star; this creates incredible pressures in the centre of the star. This leads to an implosion within the star.



Implosion then explosion
This implosion causes the star's inner layers to bounce off the dense iron core, thus creating the spectacular Type II supernova explosion.

The star that won't die

Shells surrounding the massive star
Prior to the supernova, shells of gas are thought to be surrounding the star, most probably swept out by the star's stellar winds.

The initial explosion
The instigating Type II supernova then occurred. This category of supernova correlates with the spectra analysed by the astronomers.

Colliding with the layers
The shock wave sent the star's outer layers travelling at thousands of kilometres per second, encountering shells of slower-moving material on its travels.

Changes in brightness
Each encounter with a shell of material would cause the continuous luminosity increase, and the kinetic energy created would be converted into light.

© NASA; Tobias Roetsch; ESA/ECF

Arcavi hopes to use the Hubble Space Telescope to look closer at the stellar neighbourhood

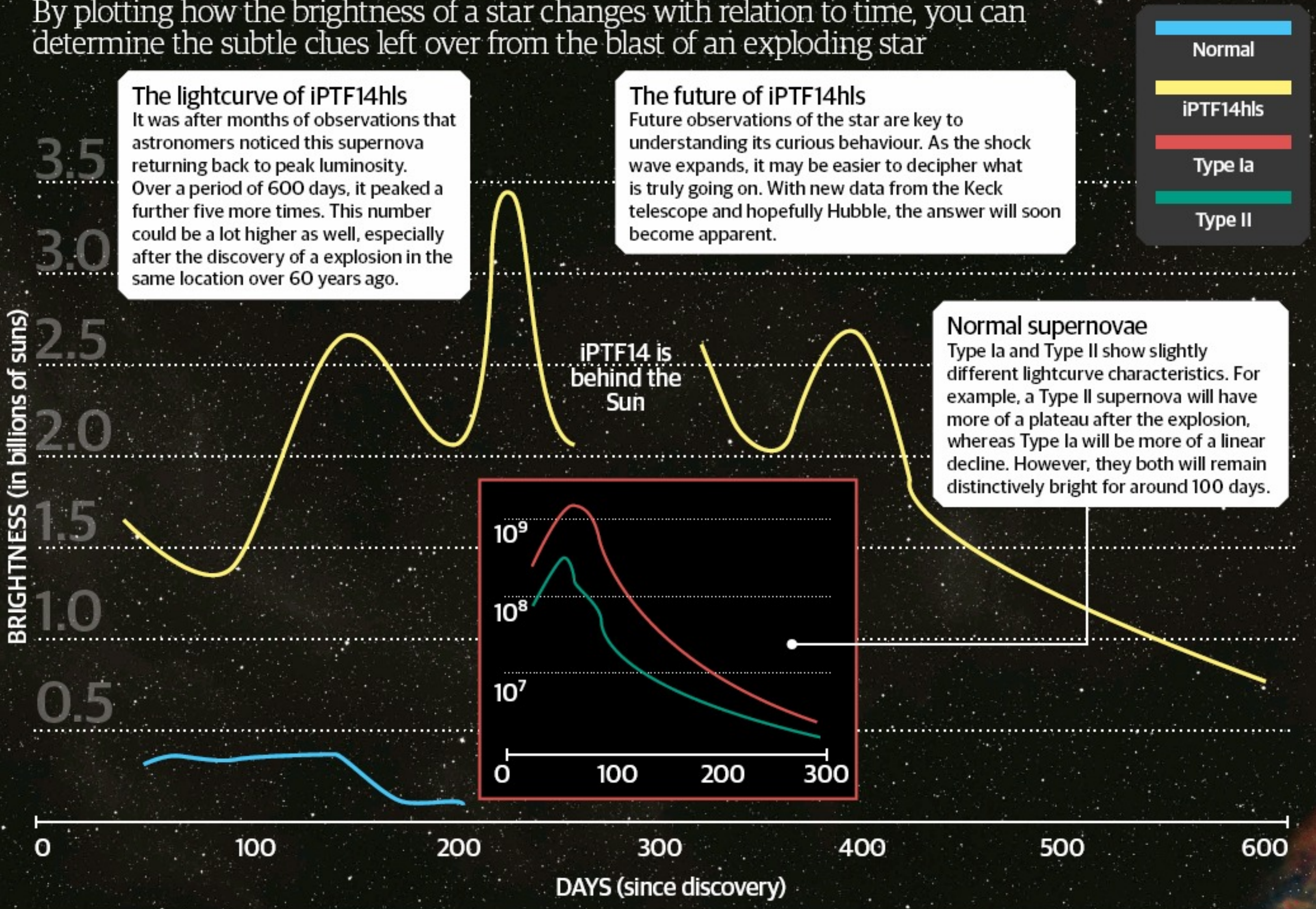
To put that into further context, that is over 300-million-times bigger than the Earth. Arcavi even made a point to say "this could be the most massive star we've ever seen explode".

These types of massive stars are the most volatile and dramatic stars in the universe and follow the rock-and-roll lifestyle of 'living fast and dying young'. Although these stars will only live for a few million years – which is young in cosmic standards – what they do in terms of supplying the universe with energy and material is vital. As mentioned previously, these massive stars create elements from helium to iron before these are cast off into the universe via a spectacular supernova. As human beings, we are made up of these elements. Hydrogen and oxygen formulate water, which makes up around 60 per cent of an adult's body. Iron is needed in our red blood cells to carry oxygen to our muscles and revitalise them. Carbon is the basic building block of proteins, carbohydrates and fats, among others. These elements makes us who we are, and they originate from the death of these stellar giants.

However, understanding what is happening to the star is a lot more complicated. When asked what is happening to the star for this to occur, Arcavi replied,

What do lightcurves say about the supernova?

By plotting how the brightness of a star changes with relation to time, you can determine the subtle clues left over from the blast of an exploding star



The lightcurve of iPTF14hls
It was after months of observations that astronomers noticed this supernova returning back to peak luminosity. Over a period of 600 days, it peaked a further five more times. This number could be a lot higher as well, especially after the discovery of a explosion in the same location over 60 years ago.

The future of iPTF14hls
Future observations of the star are key to understanding its curious behaviour. As the shock wave expands, it may be easier to decipher what is truly going on. With new data from the Keck telescope and hopefully Hubble, the answer will soon become apparent.

Normal supernovae
Type Ia and Type II show slightly different lightcurve characteristics. For example, a Type II supernova will have more of a plateau after the explosion, whereas Type Ia will be more of a linear decline. However, they both will remain distinctively bright for around 100 days.

"The short answer is that we don't know. iPTF14hls breaks all the theoretical models of supernova behaviour that we have." However, there are some possibilities floating around that explain some of these elusive aspects.

"I think we may be converging on an explanation that involves a supernova running into shells of matter around it," Stan Woosley, director of the Center for Supernova Research at the University of California, Santa Cruz, tells **All About Space**. "The [time] duration [of the peak luminosity] is how long it takes the expanding supernova to pass through those shells, not how long it took the supernova to initially explode." The star prior to the explosion could have blown off these previously existing shells of material surrounding the progenitor star, possibly by stellar winds.

After the initial supernova sent material soaring off in all directions travelling at thousands of kilometres per second, it's thought it eventually went crashing into a slower-moving shell. This collision is what produced the kinetic energy being converted into light that travelled 500-million-light-years through the cosmos to be picked up by the iPTF telescope. It is thought this shock wave encountered many layers like this, creating the five peaks between Sepetmber 2014 and May 2015.

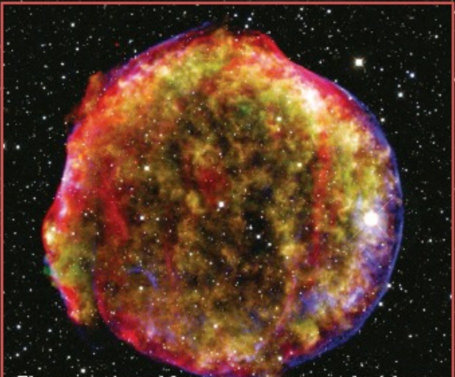
However, science is never that easy, and there are always issues. Although his theory explains the shape of iPTF14hls' lightcurve, it doesn't explain the full nature of the spectra collected. From first glance, the spectra of the star's light resembled that of a hydrogen-rich Type II supernova, which has prominent signs of hydrogen absorption lines. Counterintuitive to the point, there was no sign of the slower-moving material. Common sense would say that if there's material standing in the way of a shock wave, there should be a sign of it in the star's spectral fingerprint.

After the news of this undying star hit the headlines, many astronomers joined the search for a true answer. Roughly a month later, Jennifer Andrews and Nathan Smith of the Steward Observatory, University of Arizona, submitted a theory suggesting the supernova collided with dense circumstellar material (CSM), producing the influx of light while simultaneously masking it. While this masking effect – caused by the supernova ejecta – would hide all spectral signs of the CSM, there would also be a clear signature left from the interaction between the two.

The one thing that is clear is that there is much more work needed to be done. Arcavi hopes that the flower continues to blossom, revealing the instigator of this peculiarity: "The supernova is still shining. As the material from the explosion expands, it gets easier to see inside. However, the supernova is also fading. So we're hoping to be able to get some new clues from the inner parts of the explosion that are now being revealed before it gets too faint to detect."

So, the countdown is on. This dedicated team of astronomers continue to get as much information as they can on its decline. Since its discovery, there has been new spectrum data collected by the W. M. Keck Observatory, Mauna Kea, Hawaii. There are also plans to use the Hubble Space Telescope and take advantage of its incredible high-resolution power. Until then, these astronomers will continue to scratch their heads as they try and unravel the mystery of the star that just refuses to stop shining.

A supernova can reach the luminosity equivalent to billions of our Sun's luminosity


Elements ejected from a supernova replenish the interstellar medium

The Keck Observatory has already gathered new spectral data on the undying star

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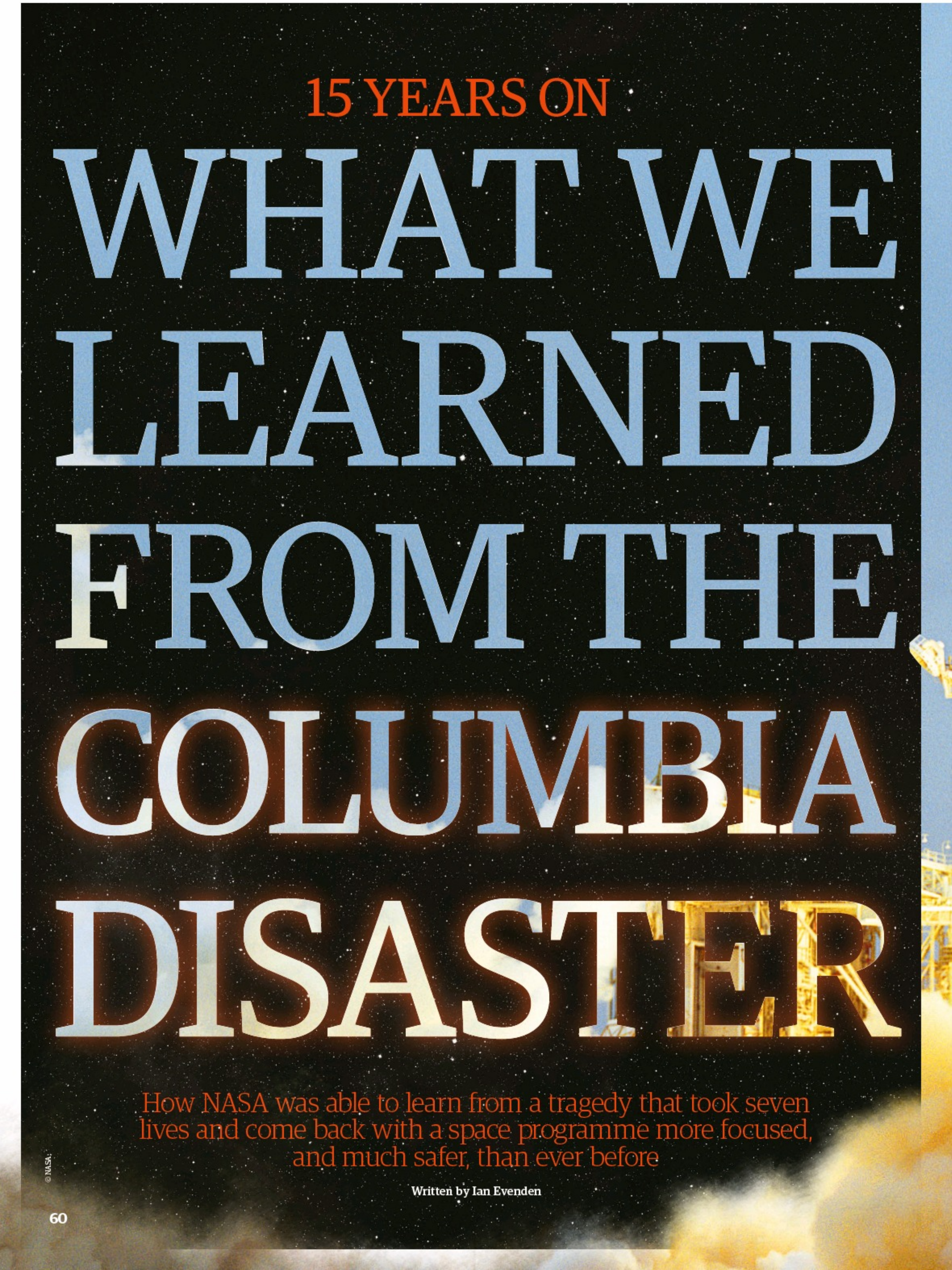


© NASA

15 YEARS ON

WHAT WE LEARNED FROM THE COLUMBIA DISASTER

How NASA was able to learn from a tragedy that took seven lives and come back with a space programme more focused, and much safer, than ever before

Written by Ian Evenden

The US space shuttles were the world's first reusable spacecraft

"This day has brought terrible news and great sadness to our country," said President George W Bush in an address made on 1 February 2003." The Columbia is lost, there are no survivors." Seven astronauts lost their lives as the Space Shuttle, the first of NASA's fleet to fly and a veteran of 4,808 orbits of the Earth, broke up in the skies above Texas.

The cause of the disaster was damage to the shuttle's left wing, caused when a large piece of insulating foam fell from the external fuel tank on launch, leaving a hole in the reinforced carbon panels. Nearly 16 days later, as Columbia made its way back to Earth, superheated atmospheric gases, penetrated the wing and destroyed its internal structure. This led to a total loss of control, causing the shuttle to break apart as it travelled at over 18-times the speed of sound.

Following the loss of Columbia, NASA overhauled its safety procedures, changing everything from the astronauts' seats to the very position future spacecraft will sit in on their launch vehicles. The changes went deeper into NASA culture too, with the Engineering and Safety Center performing testing and analysis on every mission.

Shuttles shedding foam on launch - particularly the foam from the bipod ramp, a purely aerodynamic part of the thermal protection system (TPS) where the shuttle joins the main external fuel tank - had happened before. Back in 1983, the shuttle Challenger completed its mission successfully despite losing bipod ramp foam, and even survived window damage from being struck by space debris while in orbit. Further examples of foam shedding were logged over the next 20 years, including a 2002 Atlantis launch - a construction mission for the ISS - which had been carrying an external camera to look out for just this sort of thing.

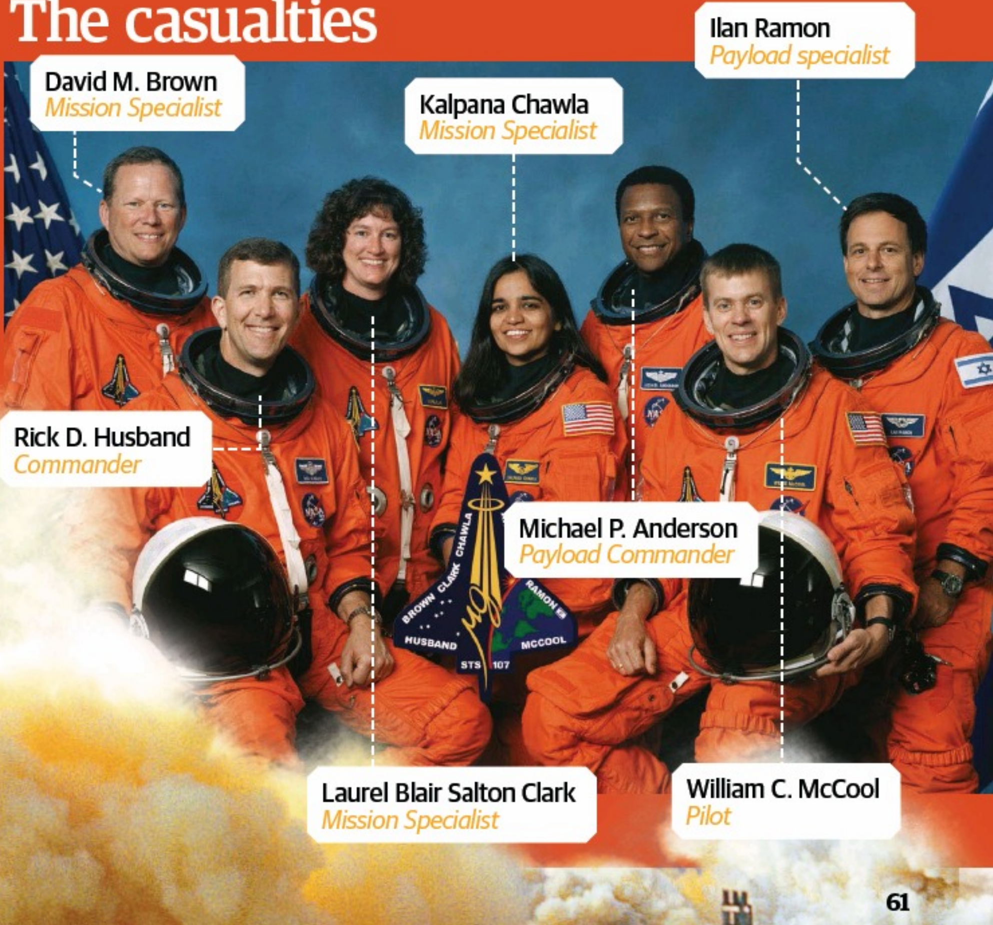
Despite this, in 2003 the shuttle's controllers deemed it an acceptable risk. As the astronaut Gus Grissom, who died in the Apollo 1 fire, said back in 1965: "If we die, we want people to accept it. The conquest of space is worth the risk of life."

The leading edges of the shuttle's wings were coated in reinforced carbon-carbon, or RCC, a material noted for its heat-proof properties, which is also used in the nose cones of nuclear missiles and the brakes of Formula One cars. While it's less brittle than some ceramic materials, it still doesn't have a high degree of impact resistance.

Following the loss of Columbia, the Southwest Research Institute in San Antonio, Texas, used an air cannon to fire foam blocks at RCC panels from the leading edges of the wings of Discovery, having flown 30 missions and Atlantis, who had 27 previous missions. Under this bombardment, a crack appeared in Discovery's panel and a substantial hole appeared in Atlantis' panel. This clearly demonstrated the effect of a foam impact.

Back on the mission, with Columbia safely in orbit, another decision was made. Despite requests from engineers, shuttle managers chose not to examine the exterior of the shuttle photographically,

The casualties



Columbia in orbit in 1995, about to deploy the Microgravity Laboratory-2 from its cargo bay

which could have involved ground-based telescopes and the cameras of Department of Defense spy satellites, or sending the astronauts on an EVA. Instead, NASA modelled the foam strike mathematically, but didn't reach a firm conclusion as to whether there had been any damage.

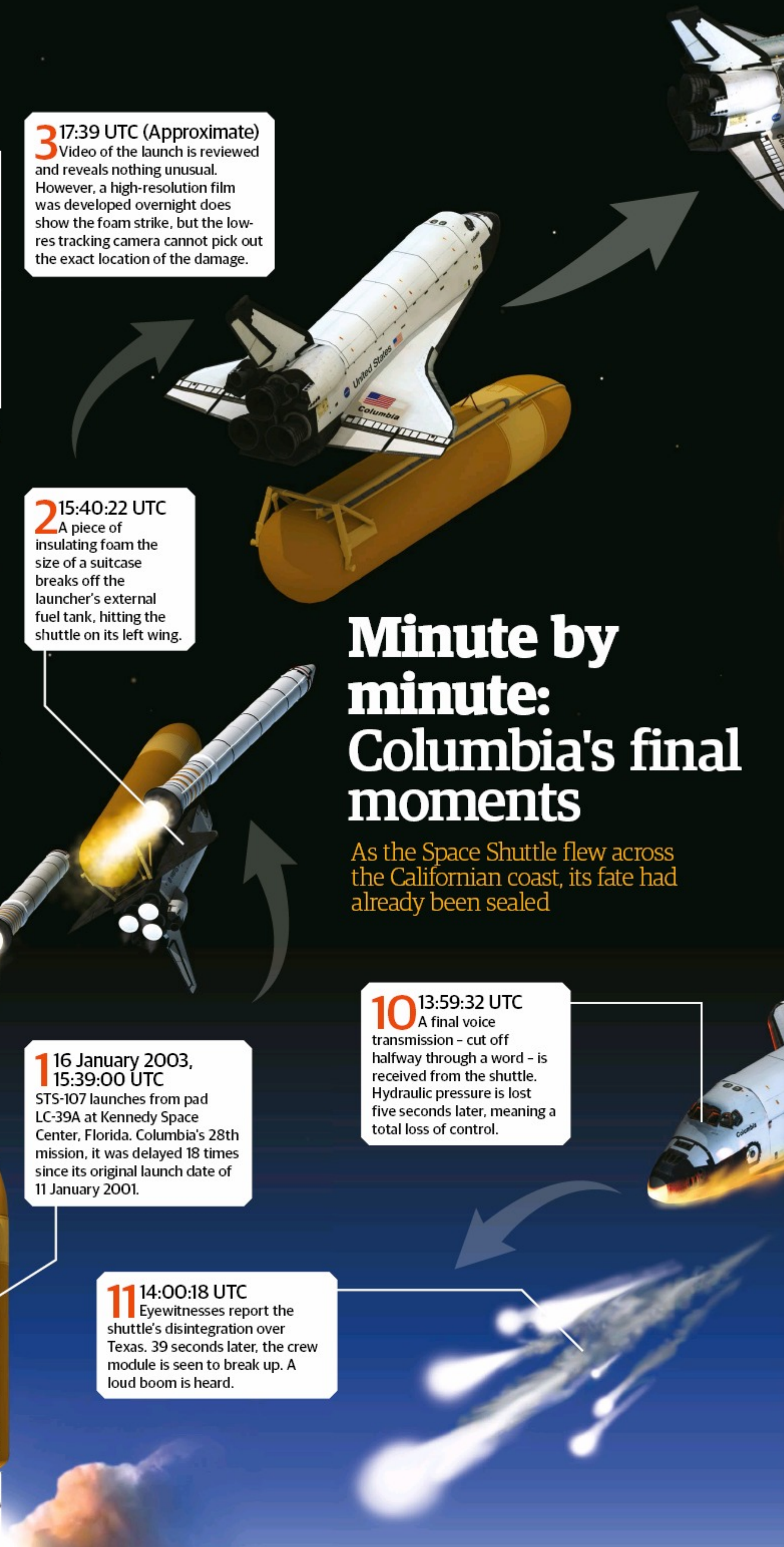
The assessment was that there was nothing that could have been done. Writing in 2013, retired NASA Space Shuttle Program deputy manager N. Wayne Hale recalled something said by Jon C. Harpold, the director of mission operations: "There is nothing we can do about damage to the TPS. If it has been damaged it's probably better not to know. I think the crew would rather not know. Don't you think it would be better for them to have a happy successful flight and die unexpectedly during entry than to stay on orbit, knowing that there was nothing to be done, until the air ran out?" Hale continues: "That mindset was widespread. Astronauts agreed."

Linda Ham, who led the mission management team for the STS-107 mission, spoke at the time of how this decision was made: "We were all trying to do the right thing. All along, we were basing our decisions on the best information that we had at the time," she said. "None of us felt that the analysis [of the foam strike] was faulty." "At the time, we had no indication or belief that there was anything here that was going to affect the crew, even in the long run," added Phil Engelauf, the mission operations representative on the management team.

In the appendices to the report of the Columbia Accident Investigation Board (CAIB), however, there's a modestly titled document "STS-107 In-Flight Options Assessment" that suggests an alternative scenario if the damage to Columbia had been identified. The shuttle Atlantis was being prepared for launch,

Minute by minute: Columbia's final moments

As the Space Shuttle flew across the Californian coast, its fate had already been sealed



1 16 January 2003, 15:39:00 UTC

STS-107 launches from pad LC-39A at Kennedy Space Center, Florida. Columbia's 28th mission, it was delayed 18 times since its original launch date of 11 January 2001.

2 15:40:22 UTC

A piece of insulating foam the size of a suitcase breaks off the launcher's external fuel tank, hitting the shuttle on its left wing.

3 17:39 UTC (Approximate)

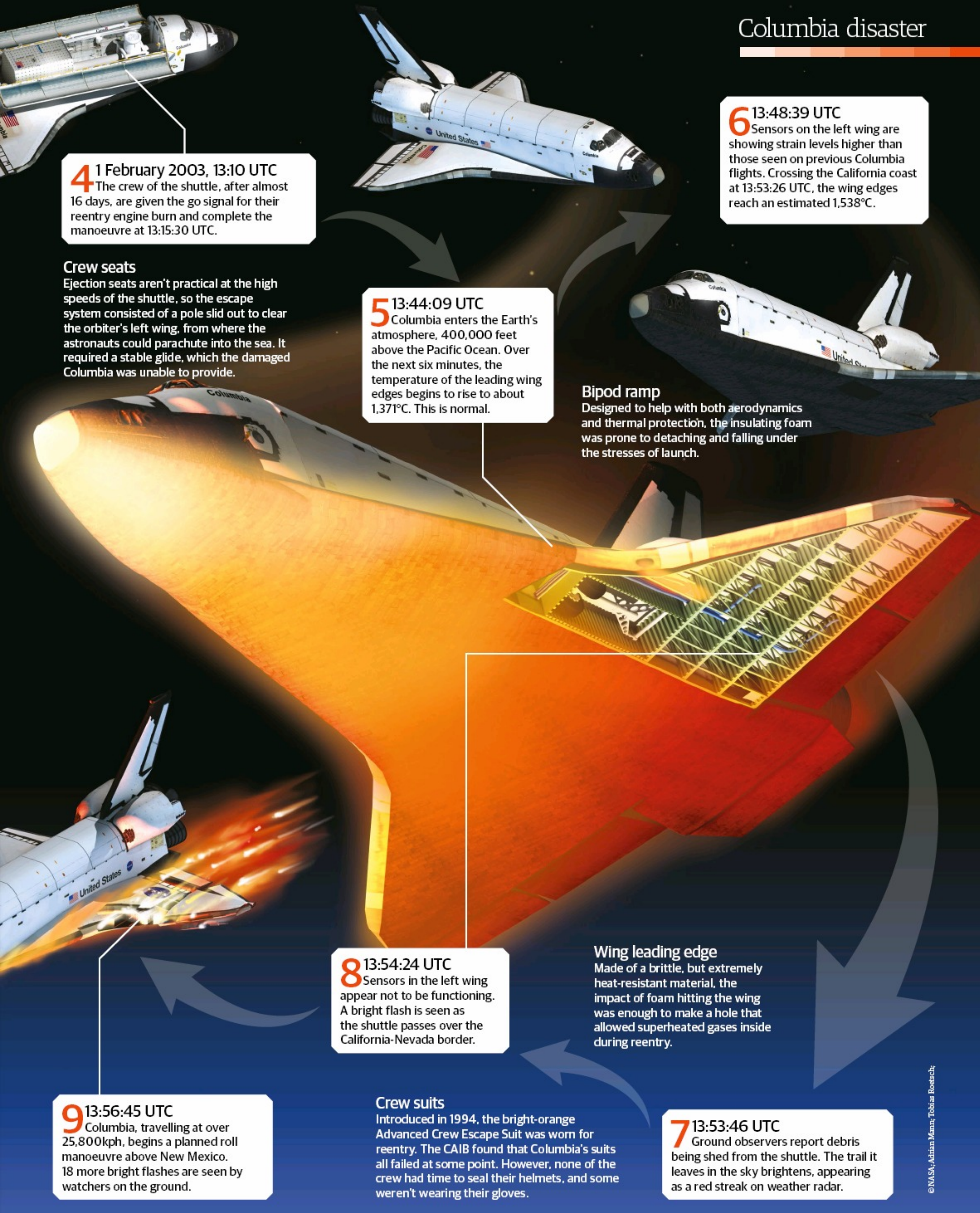
Video of the launch is reviewed and reveals nothing unusual. However, a high-resolution film was developed overnight does show the foam strike, but the low-res tracking camera cannot pick out the exact location of the damage.

10 13:59:32 UTC

A final voice transmission – cut off halfway through a word – is received from the shuttle. Hydraulic pressure is lost five seconds later, meaning a total loss of control.

11 14:00:18 UTC

Eyewitnesses report the shuttle's disintegration over Texas. 39 seconds later, the crew module is seen to break up. A loud boom is heard.



4 1 February 2003, 13:10 UTC
The crew of the shuttle, after almost 16 days, are given the go signal for their reentry engine burn and complete the manoeuvre at 13:15:30 UTC.

Crew seats

Ejection seats aren't practical at the high speeds of the shuttle, so the escape system consisted of a pole slid out to clear the orbiter's left wing, from where the astronauts could parachute into the sea. It required a stable glide, which the damaged Columbia was unable to provide.

5 13:44:09 UTC
Columbia enters the Earth's atmosphere, 400,000 feet above the Pacific Ocean. Over the next six minutes, the temperature of the leading wing edges begins to rise to about 1,371°C. This is normal.

6 13:48:39 UTC
Sensors on the left wing are showing strain levels higher than those seen on previous Columbia flights. Crossing the California coast at 13:53:26 UTC, the wing edges reach an estimated 1,538°C.

Bipod ramp

Designed to help with both aerodynamics and thermal protection, the insulating foam was prone to detaching and falling under the stresses of launch.

Wing leading edge

Made of a brittle, but extremely heat-resistant material, the impact of foam hitting the wing was enough to make a hole that allowed superheated gases inside during reentry.

7 13:53:46 UTC
Ground observers report debris being shed from the shuttle. The trail it leaves in the sky brightens, appearing as a red streak on weather radar.

8 13:54:24 UTC
Sensors in the left wing appear not to be functioning. A bright flash is seen as the shuttle passes over the California-Nevada border.

9 13:56:45 UTC
Columbia, travelling at over 25,800kph, begins a planned roll manoeuvre above New Mexico. 18 more bright flashes are seen by watchers on the ground.

Crew suits

Introduced in 1994, the bright-orange Advanced Crew Escape Suit was worn for reentry. The CAIB found that Columbia's suits all failed at some point. However, none of the crew had time to seal their helmets, and some weren't wearing their gloves.

© NASA; Adrian Mann; Tobias Roetsch;

Lessons NASA learned

Much can be drawn from the CAIB report and the wreckage of the shuttle, and NASA wasn't slow in putting them into practice

International cooperation

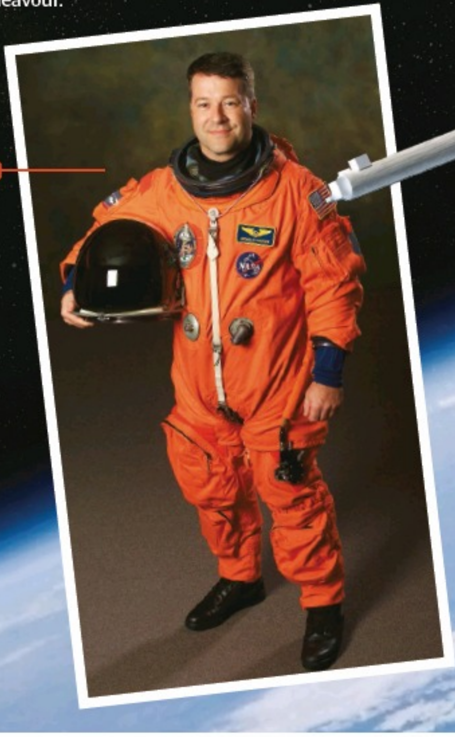
Following the retirement of the shuttle fleet, NASA has had to rely on the Russian space agency to access the International Space Station. Orion itself is an international project, with the European Space Agency providing its service module.

Commercial spaceflight is OK

After Columbia, NASA developed a programme of commercial flights to the ISS, from companies such as SpaceX and Orbital Sciences. These are unmanned cargo flights, but crew-carrying commercial launches are planned.

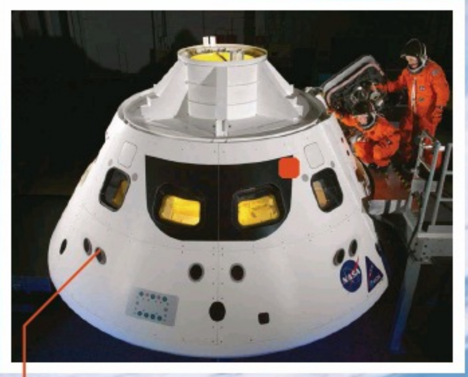
Roundworms are really tough

A live group of roundworms, around 1mm long and part of an experiment carried out in orbit, survived the Columbia crash. Some of their descendants returned to space in 2011 aboard the shuttle Endeavour.



Modified reentry suit

The ACES suit was to be replaced by the Constellation space suit, but following the cancellation of that programme ACES has been modified for greater mobility and life-support capabilities.



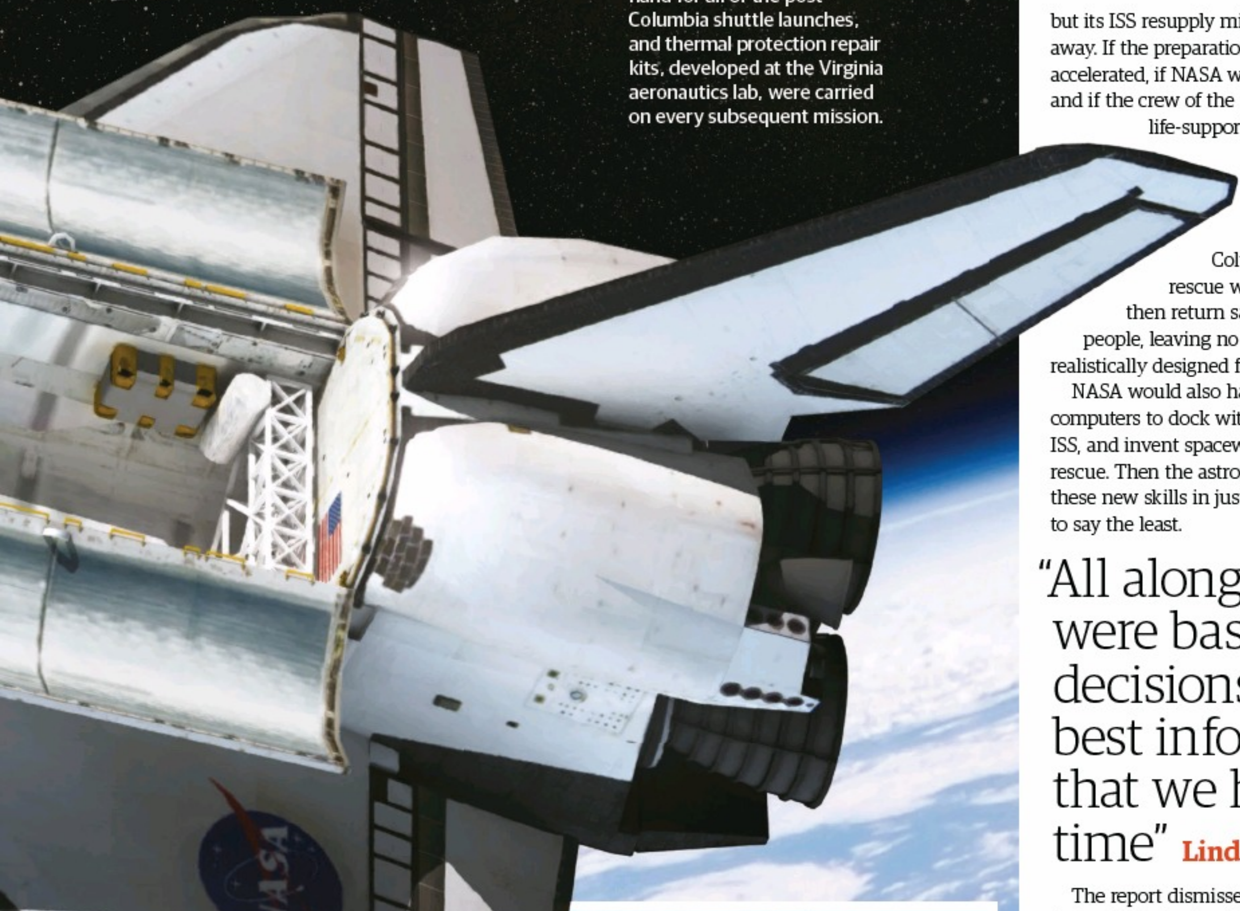
Whole new space capsule

"It is in the nation's interest to replace the shuttle as soon as possible," read the report of the CAIB. Announced in 2004, the Orion Crew Exploration Vehicle was a reaction to the recommendations.

© NASA / Kim Shiflett ; Adrian Mann; Zeynep F. Altun

Life support redesign
In the Columbia-era shuttle life-support system, an astronaut with his or her helmet's visor locked in the up position wasn't receiving any oxygen. This has been changed to ensure a constant flow of breathable gas to the helmet wearer.

The importance of research
Staff from NASA's Langley Research Center were on hand for all of the post-Columbia shuttle launches, and thermal protection repair kits, developed at the Virginia aeronautics lab, were carried on every subsequent mission.



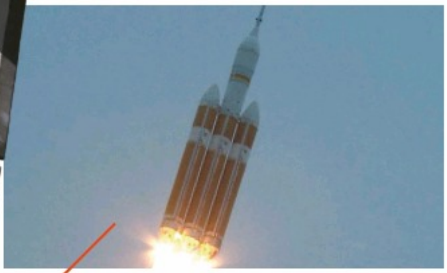
but its ISS resupply mission was still six weeks away. If the preparation process could be accelerated, if NASA would allow Atlantis to launch, and if the crew of the Columbia could stretch their life-support systems and power reserves long enough, then an in-orbit rescue was feasible, if challenging. Atlantis would have to fly, rendezvous with Columbia and carry out the rescue with a minimal crew of four, then return safely carrying the weight of 11 people, leaving no margin for error in a vehicle realistically designed for a maximum of seven.

NASA would also have had to reprogram Atlantis' computers to dock with a shuttle rather than the ISS, and invent spacewalk procedures for the actual rescue. Then the astronauts would have to learn these new skills in just two weeks. It was ambitious, to say the least.

> "All along, we were basing our decisions on the best information that we had at the time" **Linda Ham**

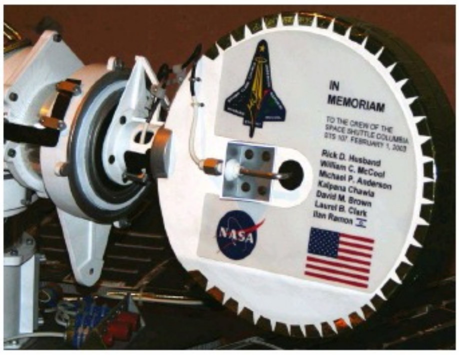
The report dismissed a further option - sending Columbia to dock with the habitable but still-under-construction ISS. Unfortunately, physics got in the way, requiring much more fuel than Columbia had available to carry out the plane-change manoeuvre that would have pushed it into the station's orbit. "Columbia's 39-degree orbital inclination could not have been altered to the ISS's 51.6-degree inclination without approximately 12,600 ft/sec of translational capability," the report says. "Columbia had 448 ft/sec of propellant available."

All of this is hypothetical, however. The decision-making process that discounted the significance of the foam shedding and chose not to inspect the shuttle is described as 'flawed' in the CAIB report, which also points out similarities to the Challenger disaster 17 years earlier, when hot exhaust burned through two O-rings in a joint and ignited the external fuel tank shortly after launch. The Rogers



Orion sits at top of rocket
By sitting on top of the launch vehicle, Orion cannot be hit by falling debris. This simple change, a return to the configuration of pre-shuttle launches, elegantly solves the problem of damage.

One of shuttle Columbia's main engine powerheads found on the grounds of Fort Polk, Louisiana



A memorial plaque mounted on the back of the high-gain antenna on the Mars rover Spirit

> "The findings and recommendations of the Columbia Accident Investigation Board will serve as NASA's blueprint" **Sean O'Keefe**

Commission, which investigated the earlier shuttle explosion, determined that NASA's internal culture and an environment of overconfidence prevented safety concerns from reaching the top decision makers, and that pressure to maintain the launch schedule had led to poor choices being made.

The clearest parallel between the two shuttle losses, however, was that NASA had long known about a problem with the rings, but that increasing levels of damage to them had been tolerated over time, based on the rationale that nothing bad had happened yet. Likewise, foam and other debris had been falling during shuttle launches since the beginning, but it took until 2003 for something 'bad' to happen.

Teams combed Texas and Louisiana for debris, organising what they found on a grid painted on the floor of the shuttle's hangar. Eventually more than 84,000 pieces of Columbia were recovered, representing some 38 per cent of the shuttle. Tellingly, there is a lot more debris from the right wing than from the left, the plasma generated by reentry having burned away the aluminium alloy used for the internal struts. Of the 137 rolls of photographic film carried on the shuttle, 21 were recovered and developed.

Following the commission's report, NASA immediately put what it had learned from the investigation into practice. Speaking at the time, NASA administrator Sean O'Keefe said: "The findings and recommendations of the Columbia Accident Investigation Board will serve as NASA's blueprint. We already have begun to take action… and we intend to comply with the full range of recommendations."

And they did. Following the loss of Columbia, and the 29 months the shuttles were grounded, there was a change in the shuttle programme. All but one of the remaining missions, before the fleet's retirement in 2011, were to the International Space Station, which was hoped could offer a safe haven for astronauts whose orbiter had suffered damage while a rescue mission was scrambled.

The odd mission out was a 2009 trip to the Hubble Space Telescope by Atlantis, adding new instruments and replacing batteries, sensors and gyroscopes. It's interesting because its trajectory meant it was in greater danger than usual of encountering orbital debris. In keeping with the new focus on safety and damage assessment after Columbia's loss, a US Navy NP-3D Orion aircraft outfitted with a long-range infrared camera was deployed to track the shuttle in flight.

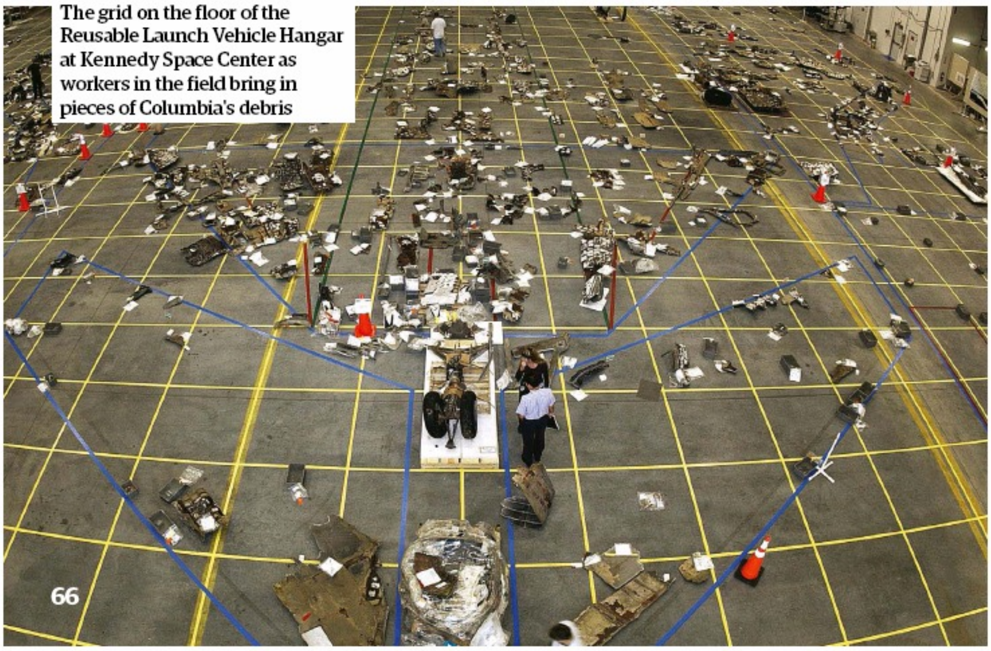
Focusing on an object flying at 15-times the speed of a bullet, while aboard a moving aircraft, would prove quite tricky – as flight operations lead Steve Tack explains: "You only have one shot. It's not like you can ask them to go around again and give us another try. It's a really exciting time, that 30 to 40 seconds when the shuttle is just screaming past us at Mach 15 and we're making a really hard turn to maintain tracking on it."

The first launch following the resumption of the programme was the shuttle Discovery on 26 July 2005. Having delivered supplies and a new module to the ISS, Discovery would go on to land safely – the only casualty being a bird that flew into the top of the rocket 2.5 seconds after ignition. However, 127.1 seconds after liftoff, debris was seen to fall from the external fuel tank. Luckily it did not hit the shuttle, but frighteningly another piece, around 20 seconds later, did.

As part of the recommendations made by the Columbia Accident Investigation Board, Discovery was carrying an Orbiter Boom Sensor System (OBSS) – a 50-foot space selfie stick that was held by the shuttle's robot arm and used a combination of cameras and lasers to scan vulnerable parts of the shuttle after it entered orbit. As a further precaution, the shuttle executed a backflip manoeuvre before docking so it could be photographed from the ISS. No damage was seen, but NASA suspended shuttle flights again until the foam problem could be solved. It would be almost a year until the next shuttle launch.

The seven crew members lost with Columbia included the first Israeli in space, fighter pilot Ilan Ramon, as well as experienced astronauts, scientists and former US Air Force and Navy personnel. A lasting tribute came in the form of seven asteroids, discovered in July 2001: 51823 Rickhusband, 51824 Mikeanderson, 51825 Davidbrown, 51826 Kalpanachawla, 51827 Laurelclark, 51828 Ilanramon and 51829 Williemccool all orbit the Sun in the asteroid belt, between Mars and Jupiter. "Asteroids have been around for billions of years and will remain for billions more," said Dr Raymond Bambery, principal investigator of the NASA Jet Propulsion Laboratory's Near-Earth Asteroid Tracking Project. "I like to think that in the years, decades and millennia ahead, people will look to the heavens, locate these seven celestial sentinels and remember the sacrifice made by the Columbia astronauts."

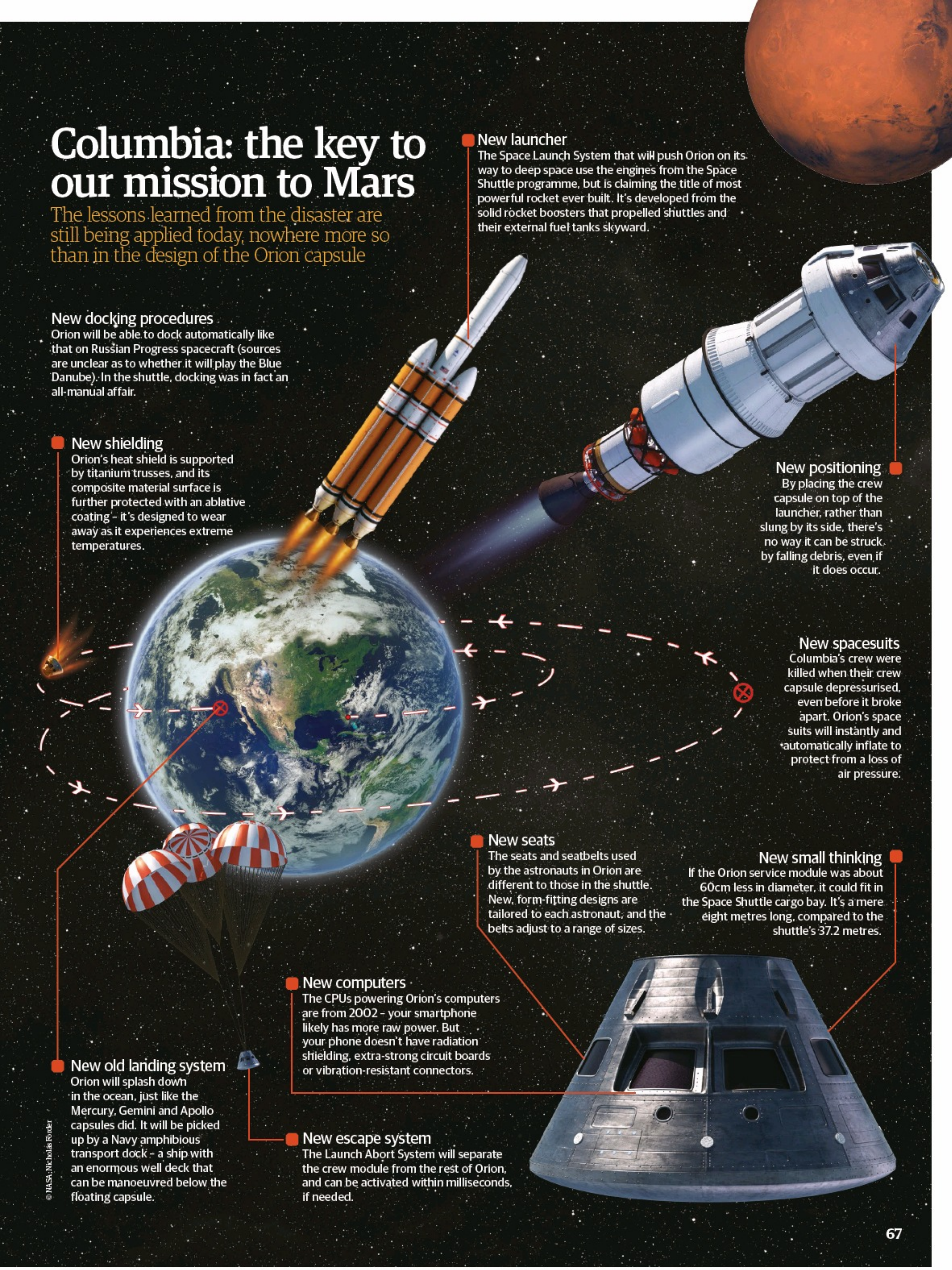
Along with those asteroids, many statues and the Columbia Memorial Station on Mars, a memorial stone to the Columbia crew stands in the Arlington National Cemetery, Virginia, also home to a memorial to the crew of the shuttle Challenger, lost in 1986. Perhaps a greater tribute to the lives lost is the continuation of the space programme, as President Bush said in his address after the Columbia's destruction: "The cause in which they died will continue… our journey into space will go on."



The grid on the floor of the Reusable Launch Vehicle Hangar at Kennedy Space Center as workers in the field bring in pieces of Columbia's debris

Columbia: the key to our mission to Mars

The lessons learned from the disaster are still being applied today, nowhere more so than in the design of the Orion capsule



New docking procedures
Orion will be able to dock automatically like that on Russian Progress spacecraft (sources are unclear as to whether it will play the Blue Danube). In the shuttle, docking was in fact an all-manual affair.

New shielding
Orion's heat shield is supported by titanium trusses, and its composite material surface is further protected with an ablative coating – it's designed to wear away as it experiences extreme temperatures.

New launcher
The Space Launch System that will push Orion on its way to deep space use the engines from the Space Shuttle programme, but is claiming the title of most powerful rocket ever built. It's developed from the solid rocket boosters that propelled shuttles and their external fuel tanks skyward.

New positioning
By placing the crew capsule on top of the launcher, rather than slung by its side, there's no way it can be struck by falling debris, even if it does occur.

New spacesuits
Columbia's crew were killed when their crew capsule depressurised, even before it broke apart. Orion's space suits will instantly and automatically inflate to protect from a loss of air pressure.

New seats
The seats and seatbelts used by the astronauts in Orion are different to those in the shuttle. New, form-fitting designs are tailored to each astronaut, and the belts adjust to a range of sizes.

New small thinking
If the Orion service module was about 60cm less in diameter, it could fit in the Space Shuttle cargo bay. It's a mere eight metres long, compared to the shuttle's 37.2 metres.

New computers
The CPUs powering Orion's computers are from 2002 – your smartphone likely has more raw power. But your phone doesn't have radiation shielding, extra-strong circuit boards or vibration-resistant connectors.

New old landing system
Orion will splash down in the ocean, just like the Mercury, Gemini and Apollo capsules did. It will be picked up by a Navy amphibious transport dock – a ship with an enormous well deck that can be manoeuvred below the floating capsule.

New escape system
The Launch Abort System will separate the crew module from the rest of Orion, and can be activated within milliseconds, if needed.

© NASA; Nicholas Forder

THE ASTRO GUIDE TO

Astronomy doesn't have to be a lonely hobby. Wherever you live, there will be a star party near you

Written by Stuart Atkinson

TIP 1

PREPARE FOR ANY WEATHER

Don't assume it will be dry all the time. Take clothes appropriate for both wet and dry conditions.

Astronomy can be a very lonely and anti-social hobby. Even if you're a stargazer from a town or a city with an astronomical society, and regularly attend their meetings and observing nights, you'll still spend a lot of time on your own, standing in the dark in a farm gateway, a lay-by or a park, looking at the night sky with just a radio or the cows in the next field for company.

Now, some people like it that way. In fact, they prefer being a solo astronomer to being in a group. For them, a huge part of the appeal of the hobby is the opportunity to have precious time on their own, far away from the noise and hubbub of everyday life. They relish their special nights out there in the dark, with no-one and nothing to disturb them, savouring the unique peace and quiet offered by a night under the twinkling stars.

But for those astronomers who do want company, who do want to share the beauty of the night sky with others, there are special organised events they can go to. These events are held once or sometimes twice a year, and are held at remote sites chosen for their dark night skies. They usually, but not always, involve camping, and are mostly held over a weekend when there is little or no Moon in the sky.

These organised events offer astronomers a chance to get together and enjoy the wonders of the heavens together, under a sky much darker than the one they have at home. During the daytime there are often talks and lectures by guest speakers, trade stands to buy equipment from and workshops offering advice on using equipment. Then, after dark, if the weather is kind, everyone is free to wander around looking through each other's telescopes, enjoying spectacular views they could never hope to see back home.

These events are called star parties.

© VWPics / Getty Images

NOMER'S STAR PARTIES

WHAT YOU'LL NEED ☑

Warm clothing

☐ You'll (hopefully!) be outside observing all through the night, so you'll need to wrap up properly.

Wellies

☐ If it rains the star party site could get very wet and muddy, so be sure to take your waterproof boots!

A red torch

☐ You'll need something to find your way around safely in the dark. Cover its front with red film to preserve everyone's night vision.

Binoculars

☐ A good pair of binoculars is a star-party must. They'll offer you fantastic views of celestial objects under a dark sky.

Telescope

☐ If you have a telescope, take it, but if you don't it doesn't matter; you'll be encouraged to look through other people's.

Camera and tripod

☐ You'll want to take advantage of the dark sky to take photos of the constellations, so don't forget your camera!

Star chart

☐ Take a set of star charts or a star atlas to help you find your way around – you'll be disoriented seeing many faint stars you can't normally see.

Mobile phone or tablet with astronomy apps

☐ Planetarium apps on your mobile device will be invaluable for helping you find your way around the sky.

Contact information cards

☐ Be sure to take some cards with your contact details on so you can give them to people you want to keep in touch with afterwards.

Some reading material

☐ Be sure to take something to read on any cloudy nights during the star party.

TIP 2

TAKE SPARE EVERYTHING

Make sure you have packed plenty of spare batteries for your camera, torch, telescope and star tracker before setting off.

Star parties are usually held around the new Moon for darker skies

WHAT TO EXPECT AT A STAR PARTY

Many star parties also involve camping, especially the weekend events

Making the decision to go to your first star party can be a bit daunting. After all, it's a step out of your comfort zone and into the unknown. Will you fit in? Will you be welcomed as a newcomer with open arms, or will you feel like a stranger walking into a busy saloon bar, when the piano player falls silent and every head turns to look at you?

Relax. Star parties are very welcoming events, run by enthusiasts who were once newcomers just like you. Star parties have their regular attendees, of course, but their organisers really do welcome new people, and work very hard to make them feel included in their events. You won't feel like an intruder.

Because star parties are held at remote locations with dark skies, attending one usually - but not always - involves camping. People pitch their tents, or roll up in their mobile homes or caravans, and enjoy the sky together for a weekend. Some star party sites have lots of facilities - hook-up electricity, showers, warm rooms, kitchen facilities - but others are very basic and are essentially just a field. You have to choose which type of star party is right for you.

TIP 3

DON'T RUSH FROM TELESCOPE TO TELESCOPE

Take your time looking through each telescope, each view will be different.

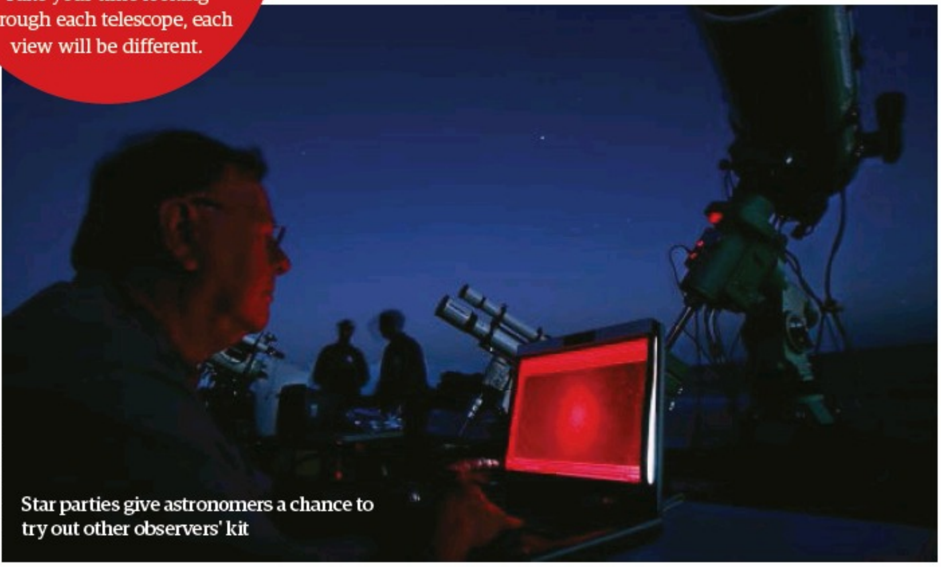
Wherever it is held, at a star party the emphasis is on sharing - sharing information, advice and wonderful views of the sky. Daytimes can often be very busy. If the Sun comes out there will be at least one person there with a solar telescope set up to show people gorgeous views of any sunspots and prominences visible on the Sun's surface. If it's cloudy it doesn't matter, because there are usually talks given by guest speakers, and many star parties hold workshops to help attendees get the most from their equipment or learn about astrophotography and practical observing, too. Most star parties are supported by traders who set up their stalls and have observing and photographic equipment for sale, sometimes at specially discounted prices. And of course people just hang out together, swapping stories, comparing experiences and looking at each other's telescopes.

But it's at sunset when star parties really come to life. As the Sun goes down, an expectant hush falls over the star party. Using red torches to guide them safely around the darkening site, people go to their telescopes and start to observe, or take photographs. The still night air fills with the sound of telescope motors whirring, camera shutters clicking and whispers and laughter, as people enjoy being out under a starry sky much darker than the one they see at home.

Some people go to star parties for general sightseeing. They skip from one object to another, seeing as many different galaxies, nebulae and clusters as possible in the precious time they have there. Other people focus on one particular class of object, or even just one object, observing and photographing it very intensely.

One of the greatest joys of a star party is just wandering around, looking through the telescopes there. Although a few will be off limits because their owners are doing some serious observing or photography, most people are delighted to let you look through their telescope, and will happily swing it around to any object you really want to see.

This is my favourite thing about star parties - they give you an opportunity to look through telescopes you can only dream of owning yourself, telescopes that you will never be able to afford. Most star parties will have at least one 'monster' Dobsonian telescope set up, a great cannon pointed at the sky which offers jaw-droppingly beautiful views of Messier objects and any planets on view at the time.



Star parties give astronomers a chance to try out other observers' kit

© Handout / Getty Images

THE TYPE OF KIT YOU'LL SEE

Refractor

These high-quality telescopes are often used by experienced observers wanting to enjoy detailed views of planets and star clusters.

Newtonian reflector

Possibly the most common type of telescope you'll see at a star party, provides great views of deep-sky objects and comets.

Dobsonian

These impressive instruments provide stunning views of galaxies, nebulae and star clusters. Some of the bigger models even require a ladder!

Catadioptric

Some serious astrophotographers use these powerful, sturdy instruments to take beautiful images of the planets and deep-sky objects.

Camera & tripod

Many star-party goers are there to take photographs, and some will use just a DSL camera on a simple tripod to take beautiful images.

Sky-tracking mount

Those wanting to take long exposures will put their cameras on special mounts that track the stars as they move across the sky.

WHAT YOU'LL GET OUT OF GOING

So why should *you* go to a star party? What will you get out of it?

Firstly, and most importantly, if the weather cooperates (and you always have to go to a star party prepared for the weather to thwart your exciting plans and turn your stargazing expedition into a star-free camping trip) you will be able to enjoy being under a sky much darker, and blazing with many more stars, than the one you are used to. Star parties are held at locations with as little light pollution as possible, so if you go to one you will enjoy wonderful naked-eye views of the stars and constellations and see incredible detail in deep-sky objects when you look through the eyepieces of the larger telescopes there. If you're into astrophotography you'll also be able to take much better pictures than you can at home; the lack of light pollution will allow you to take longer exposures and record more stars and much fainter objects than you usually can.

Secondly, you'll be able to look through a lot of different telescopes and compare the views through them. This is really useful if you're considering buying your first telescope, or upgrading to a new one. As tempting and attractive as the glossy telescope ads in magazines and online are, there's just no substitute for actually looking at, and through, a variety of different telescopes to see which one would suit you. You'll learn which are too big or too small for you, which are going to be too complicated to set up and use and just get a feel for which one would be right for you.

You'll also be able to get lots of free advice from more experienced observers at the star party. There will be people there delighted to answer questions about choosing and using observing equipment, the best apps to use, how to find your way around the night sky and more.

Another great thing about star parties is that you can just wander around and enjoy thrilling views of objects through telescopes far beyond your budget. There will be beautiful long refractors giving pin-sharp views of any planets on view at the time, and huge Dobsonian reflectors offering stunning views of deep-sky objects. Looking through them you'll see the dust lanes and gracefully curved spiral arms of distant galaxies, billows and swirls of glowing gas inside nebulae and star clusters looking like piles of jewels spilled on black velvet.

Star parties are also great for helping you learn your way around the sky and appreciate its true beauty. Without light pollution drowning out the fainter stars you'll see the constellations in all their glory, not just reduced to the boring shapes you see from your back garden surrounded by streetlights. This can actually be a little confusing and disorienting at first: with so many faint stars suddenly visible, you can actually get lost as the constellation outlines you are familiar with are suddenly blended into the background of a sky awash with stars. But after you've got your bearings you'll recognise all your old friends again.

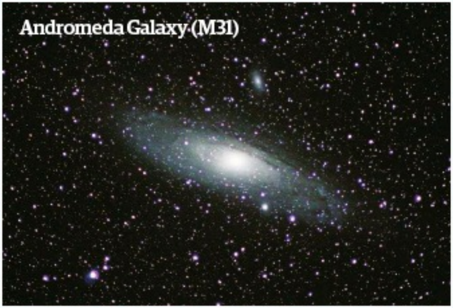
Going to a star party is a great way to recharge your stargazing batteries if you're feeling frustrated or disillusioned with the hobby. Under a truly dark sky, unspoiled by light pollution and surrounded by telescopes, you'll remember why you fell in love with astronomy in the first place, and appreciate again just how beautiful the night sky is.

Milky Way

TIP 4

TAKE A RED TORCH

Make sure your torch is covered with red film to preserve everyone's dark adaption.



Andromeda Galaxy (M31)

Orion Nebula (M42)

> "You will be able to enjoy being under a sky much darker, and blazing with many more stars, than the one you are used to"

TIP 5

DON'T BE AFRAID TO ASK QUESTIONS

Star party goers are very friendly and helpful, and will be happy to answer questions and give advice to newcomers.

TIP 6

MAKE TIME TO JUST LOOK UP AT THE STARS

Be sure to make time to just look up at and appreciate the beauty of the starry sky on clear nights during the star party.

YOUR STAR PARTY CALENDAR

COUNTRY	NAME	LOCATION	DATES	NOTES
UK	**KIELDER FOREST STARCAMP** http://www.sunderlandastro.com/star-camp/	Kielder Campsite, Kielder, Northumberland	14 – 19 March 2018	Long weekend of stargazing under some of the darkest skies in the UK. Talks and vendors. Campsite has electricity, showers and popular 'Warm Room'. Area popular for walking and cycling.
UK	**DALBY STARFEST** http://www.scarborough-ryedale-as.org.uk/saras/starfest/starfest-2018/	Adderstone Field, Dalby Forest, North Yorkshire	9 – 12 August 2018	Family-friendly starcamp held in North Yorkshire. No electricity on campsite. Wide, open sky guarantees great views of the Milky Way.
UK	**SOLARSPHERE ASTRONOMY & MUSIC FESTIVAL** http://www.solarsphere.events/	Penmaenau Farm, Builth Wells, Llanelwedd, Wales	10 – 13 August 2018	Unique mix of astronomy and music at this festival. Features lots of competitions and fun activities as well as stargazing and illustrated talks.
UK	**ASTROCAMP** http://astrocamp.awesomeastronomy.com/	Cwmdu Campsite, Crickhowell, Powys, North Wales	14 – 17 April 2018 8 – 11 September 2018	Very popular star camp under a very dark sky. Lots of fun and social activities to enjoy during the daytime.
UK	**DUMFRIES & GALLOWAY STAR PARTY** http://www.drumroamin.co.uk/	Drumroamin Campsite	19 – 25 March 2018	Very dark, remote site. One of darkest skies in the whole of the UK. Limited facilities on-site but very popular event.
UK	**SKELLIG STAR PARTY** http://skelligstarparty.com/	Skellig Lodge, Ballinskelligs, Ring of Kerry, County Kerry, Ireland	10 – 12 August 2018	Most popular star party in Ireland, attracts stargazers from all over the UK. Very attractive location on Irish coast makes it especially popular with astrophotographers.
US	**STELLAFANE CONVENTION** https://stellafane.org/convention/	Breezy Hill, Springfield, Vermont, USA	9 – 12 August 2018	Mainly a gathering for skilled telescope makers, but also features stargazing. Lots of workshops and presentations.
US	**OKIE-TEX STAR PARTY** http://www.okie-tex.com/	Camp Billy Joe, Oklahoma	6 – 14 October 2018	Very popular star party at a very dark location.
US	**TEXAS STAR PARTY** https://texasstarparty.org/	Prude Ranch, Nr Fort Davis, Texas	6 – 13 May 2018	One of the largest and most popular star parties held in the US.
US	**GRAND CANYON STAR PARTY** http://tucsonastronomy.org/upcoming-events/grand-canyon-star-party/	South Rim, Grand Canyon National Park Arizona	9 – 16 June 2018	Very popular star party held near one of the most famous natural landmarks in the US. Few daytime activities as most people sightsee at the Grand Canyon.
GERMANY	**HERZBERGER TELESCOPTREFFEN** http://www.herzberger-teleskoptreffen.de/	Jeßnigk, Dorfstraße 118 D - 04916 Jeßnigk-Schönewalde	6 – 9 September 2018	One of the largest and most popular German star parties. Attendees enjoy workshops and lectures. Cafes and even a restaurant on-site. Lots of large telescopes, often including a 42" refkector!
AUSTRALIA	**SOUTH PACIFIC STAR PARTY** http://www.asnsw.com/node/712	Wiruna near Ilford, NSW, between Lithgow and Mudgee	10 – 13 May 2018	One of the southern hemisphere's largest star parties, held at a 100-acre dark-sky site. Regularly attended by between 200-400 people.
HUNGARY	**HUNGARIAN ASTRONOMICAL ASSOCIATION**	Near Tarjan Village, Hungary	TBA	Very popular meeting organised by the Hungarian Astronomical Association, named after their members' magazine, *Meteor*.
SOUTH AFRICA	**KAROO STAR PARTY** http://www.pretoria-astronomy.co.za/pdf/kambro_2018.pdf	Kambro guest farm, 20km north of Britstown Karoo	9 – 12 August 2018	Small-scale star party held under the dark South African skies. Fantastic views of the southern Milky Way.
CANADA	**STARFEST 2018** http://www.nyaa.ca/index.php	River Place Park, West Grey, Ontario	9 – 12 August 2018	One of the largest and most popular star parties in Canada. Clear skies would guarantee excellent views of the Perseid meteor shower.

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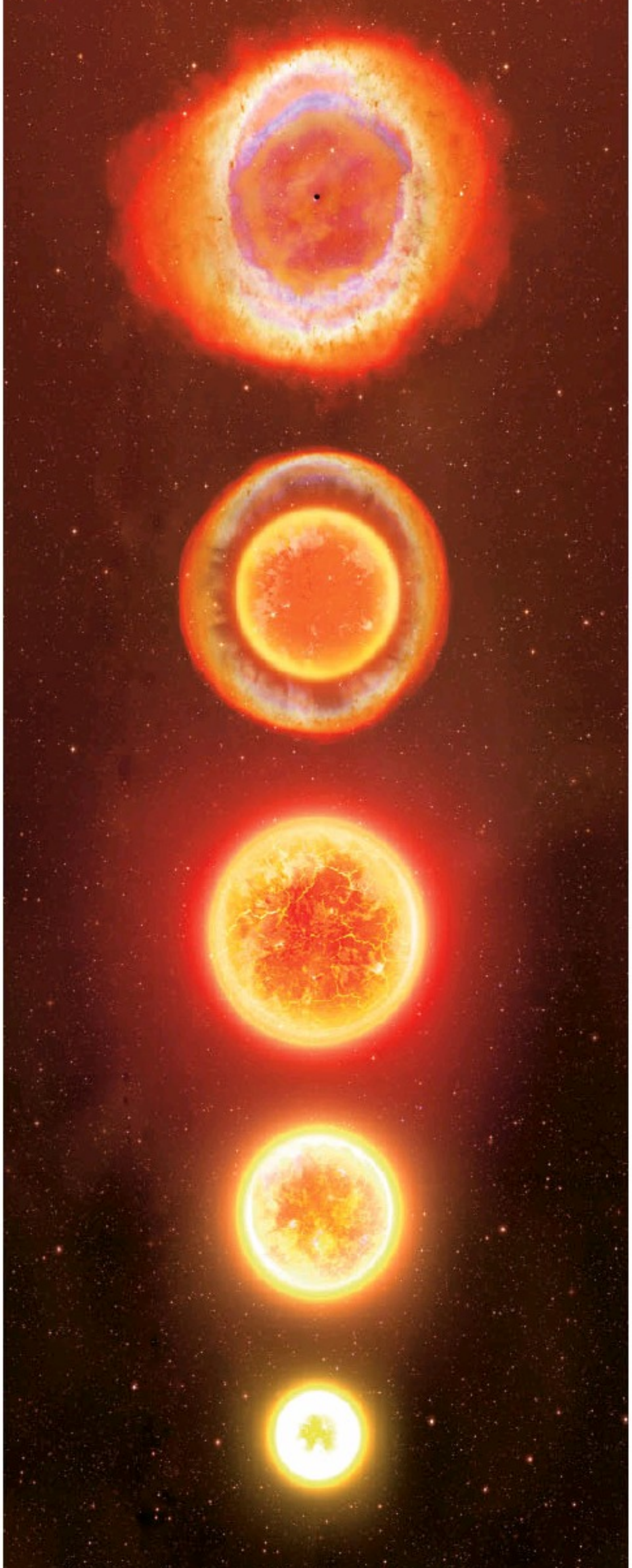

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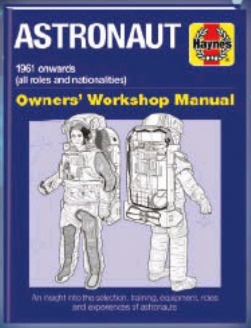

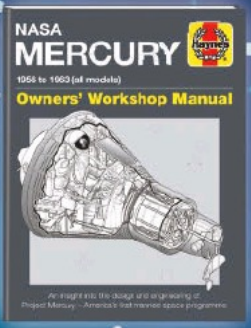

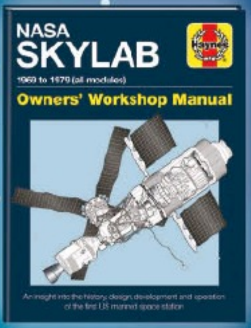

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STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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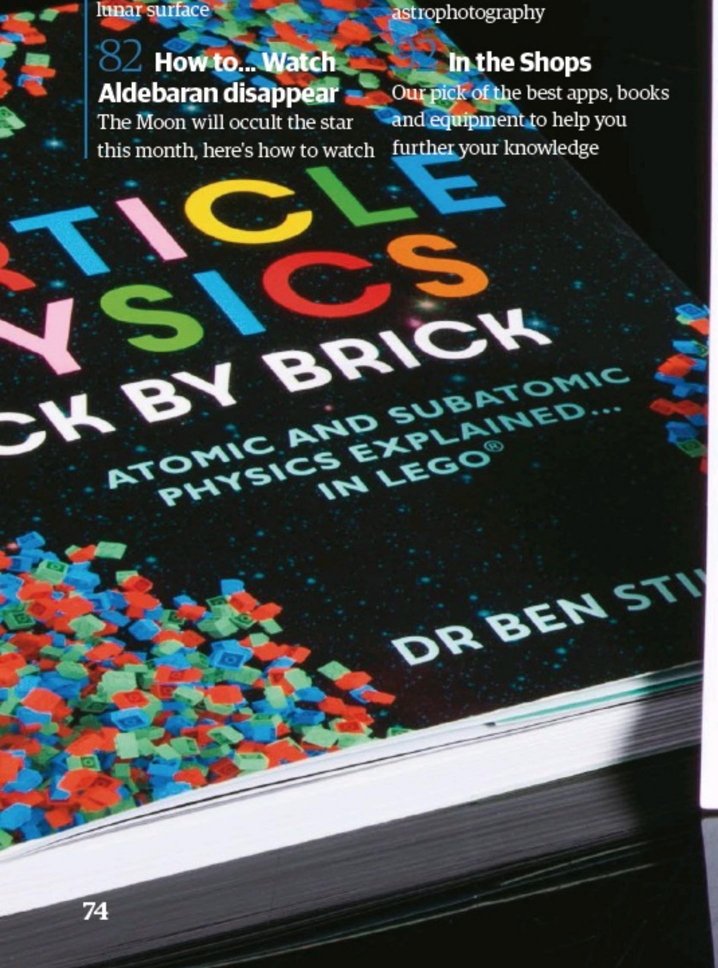

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In order to preserve your night vision, you should read our observing guide under red light

7 FEB
Globular cluster NGC 2808 in Carina is well placed for observation

©NASA/ESA

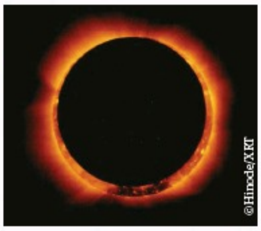
7 FEB
Conjunction between the Moon and Jupiter in Libra

©joka2000

9 FEB
Conjunction between the Moon and Mars in Ophiuchus

9 FEB
The Moon and Mars make a close approach, passing within 4°18' of each other in Ophiuchus

15 FEB
Partial solar eclipse visible from South Georgia, Falkland Islands, Argentina, Chile and Uruguay


©Hinode/XRT

18 FEB
Mercury is well placed for observation, shining brightly at a magnitude of -1.7

©tesposito2255

20 FEB
Comet C/2015 O1 (PANSTARRS) will make its closest approach to the Sun, glowing at 13.1

27 FEB
Open cluster IC 2581 is well placed for observation in Carina

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

7 FEB

The Moon and Jupiter make a close approach, passing within 4°07′ of each other in Libra

© Radoslaw Ziomber

11 FEB

Conjunction between the Moon and Saturn in Sagittarius

11 FEB

The Moon and Saturn make a close approach, passing within 2°27′ of each other in Sagittarius

19 FEB

Bode's Galaxy (Messier 81) is well placed for observation in Ursa Major

20 FEB

Open cluster NGC 3114 in Carina is well placed for observation

© Roberto Mura

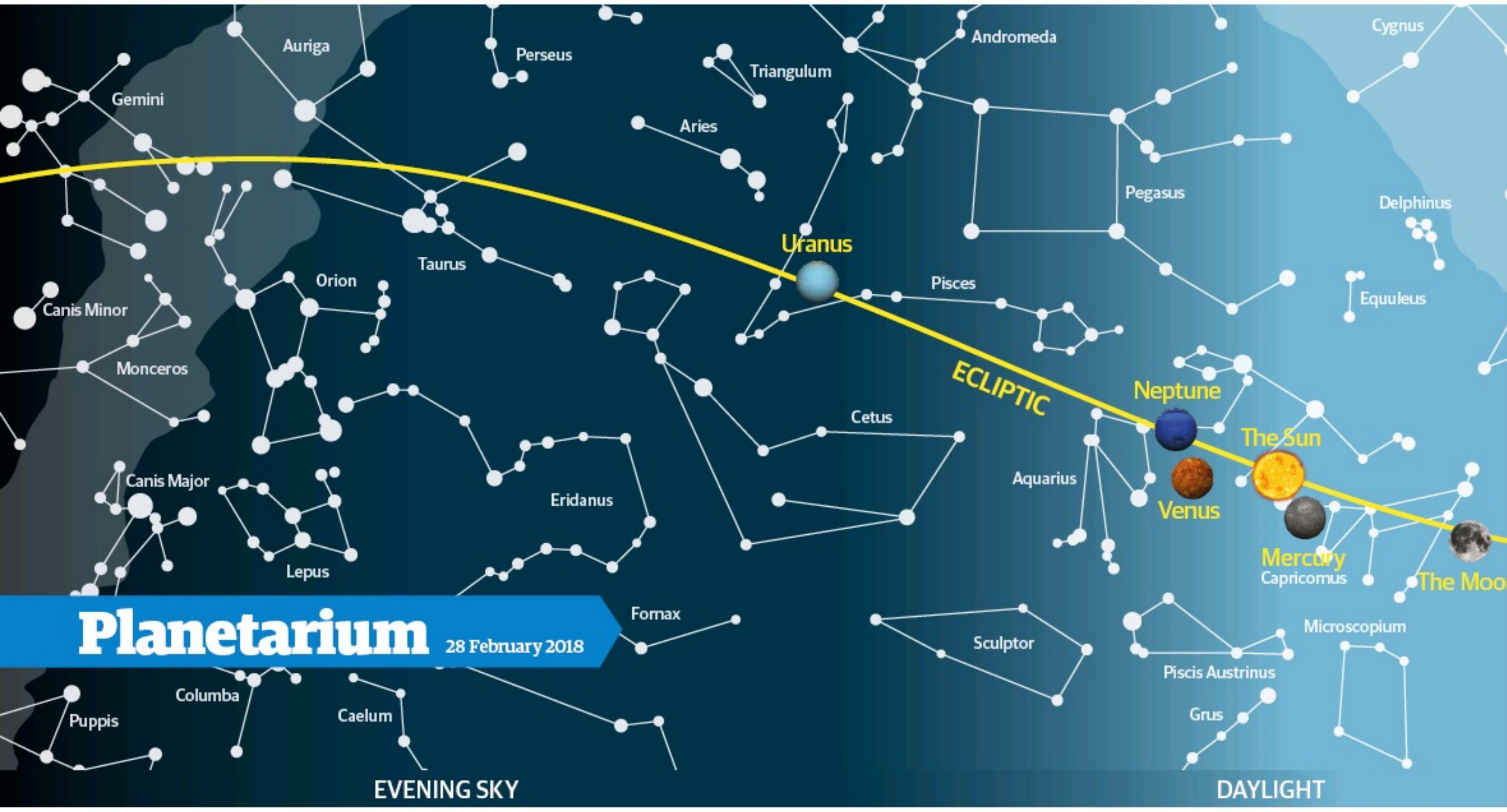
©Ganuson

27 FEB

Open star cluster NGC 884 is well placed for observation, glowing at magnitude 4 in Perseus

Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope

STARGAZER



Planetarium

28 February 2018

Moon calendar

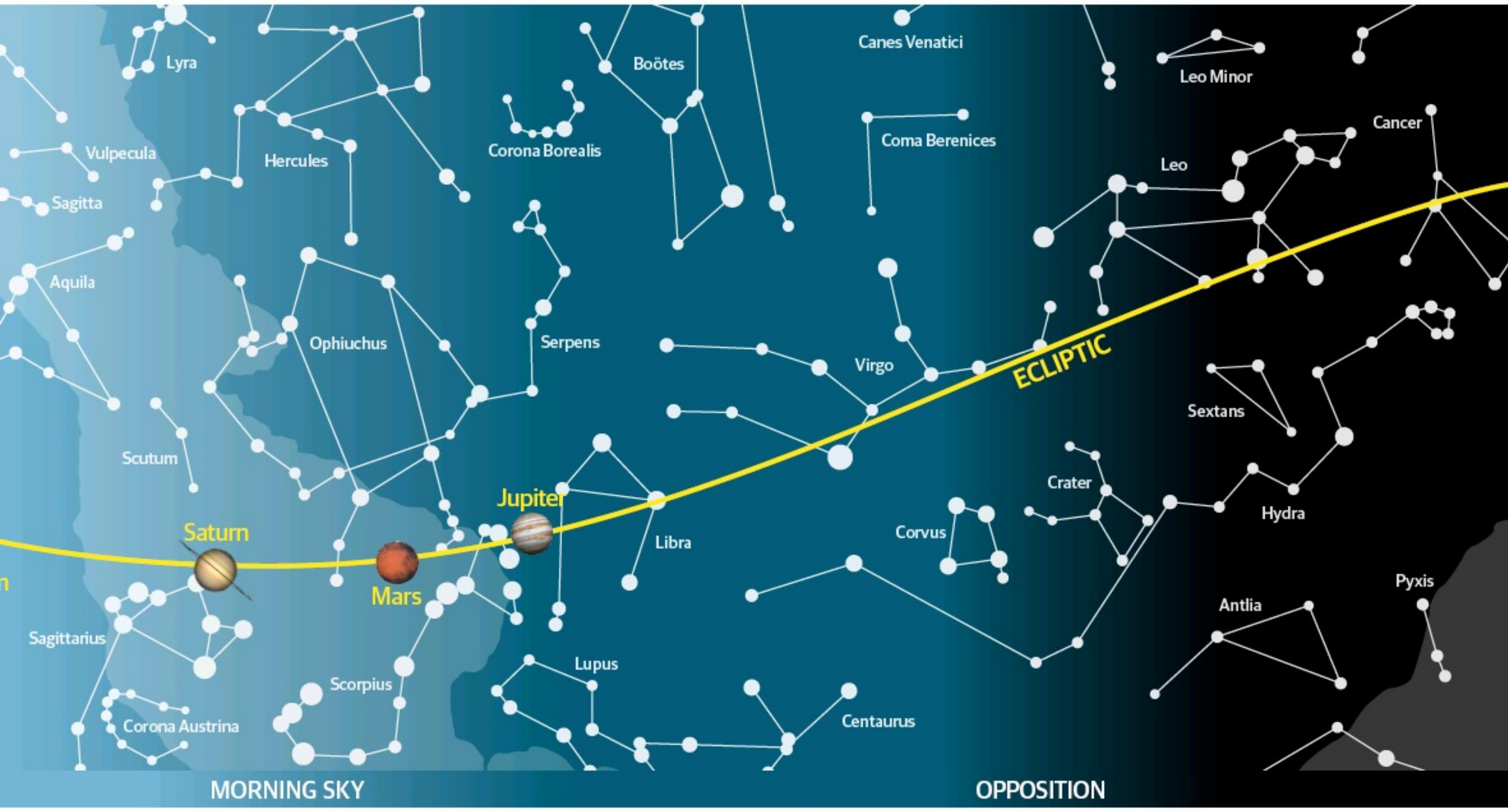
* The Moon does not pass meridian on 1 March

			1 FEB 99.7% ▼08:12 ▲18:14	2 FEB 96.8% ▼08:45 ▲19:34	3 FEB 91.1% ▼09:13 ▲20:51	4 FEB 83.5% ▼09:38 ▲22:05
5 FEB 74.4% ▼10:02 ▲23:16	6 FEB 64.5% ▼10:26 ▲--:--	7 FEB TQ 54.3% ▲00:24 ▼10:51	8 FEB 44.2% ▲01:30 ▼11:18	9 FEB 34.6% ▲02:33 ▼11:49	10 FEB 25.6% ▲03:33 ▼12:25	11 FEB 17.6% ▲04:28 ▼13:07
12 FEB 10.8% ▲05:17 ▼13:56	13 FEB 5.5% ▲06:01 ▼14:50	14 FEB 1.9% ▲06:38 ▼15:50	15 FEB NM 0.1% ▲07:10 ▼16:54	16 FEB 0.4% ▲07:38 ▼18:00	17 FEB 2.9% ▲08:04 ▼19:08	18 FEB 7.4% ▲08:27 ▼20:07
19 FEB 14.0% ▲08:50 ▼21:28	20 FEB 22.4% ▲09:13 ▼22:39	21 FEB 32.3% ▲09:38 ▼23:52	22 FEB 43.3% ▲10:07 ▼11:34	23 FEB FQ 55.0% ▼01:06 ▲10:41	24 FEB 66.6% ▼02:19 ▲11:23	25 FEB 77.4% ▼03:27 ▲12:14
26 FEB 86.8% ▼04:29 ▲13:17	27 FEB 94.0% ▼05:21 ▲14:28	28 JAN 98.4% ▼06:05 ▲15:45	1 MAR --.-%* ▼06:40 ▲17:04			

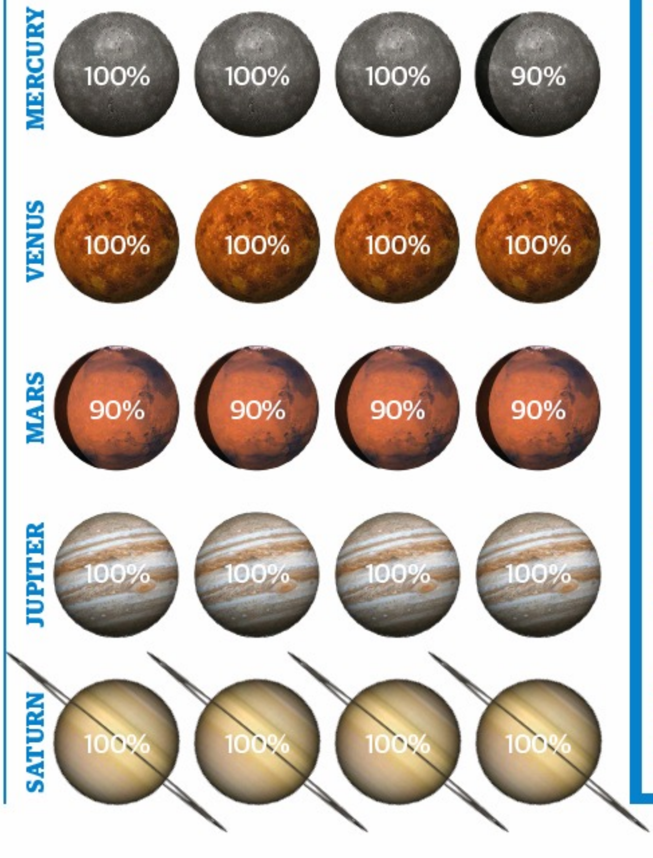
% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	07 FEB	14 FEB	21 FEB	28 FEB
MERCURY	100%	100%	100%	90%
VENUS	100%	100%	100%	100%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	01 Feb	20h 12m 10s	-21° 43' 30"	Capricornus	-0.6	07:21	15:30
	07 Feb	20h 53m 03s	-21° 43' 30"	Capricornus	-0.6	07:25	16:01
	14 Feb	21h 41m 15s	-16° 03' 23"	Capricornus	-1.4	07:24	16:43
	21 Feb	22h 29m 45s	-11° 20' 45"	Aquarius	-1.6	07:19	17:30
	28 Feb	23h 17m 54s	-05° 37' 05"	Aquarius	-1.4	07:09	18:20
VENUS	01 Feb	21h 20m 31s	-16° 56' 37"	Capricornus	-3.9	08:00	17:08
	07 Feb	21h 50m 15s	-14° 35' 57"	Capricornus	-3.9	07:52	17:27
	14 Feb	22h 24m 02s	-11° 33' 55"	Aquarius	-3.9	07:42	17:50
	21 Feb	22h 57m 00s	-08° 16' 48"	Aquarius	-3.9	07:30	18:13
	28 Feb	23h 29m 18s	-04° 49' 04"	Aquarius	-3.9	07:17	18:35
MARS	01 Feb	16h 04m 47s	-20°08' 38"	Scorpius	1.2	03:04	11:33
	07 Feb	16h 20m 08s	-20° 52' 01"	Scorpius	1.1	03:01	11:21
	14 Feb	16h 38m 06s	-21° 36' 10"	Ophiuchus	1.0	03:32	13:30
	21 Feb	16h 56m 05s	-22° 13' 11"	Ophiuchus	0.9	02:51	10:52
	28 Feb	17h 14m 02s	-22° 43' 01"	Ophiuchus	0.8	02:44	10:39
JUPITER	01 Feb	15h 15m 30s	-16° 56' 01"	Libra	-2.0	01:56	11:04
	07 Feb	15h 17m 53s	-17° 04' 17"	Libra	-2.0	01:35	10:42
	14 Feb	15h 20m 09s	-17° 11' 53"	Libra	-2.1	01:11	10:16
	21 Feb	15h 21m 53s	-17° 17' 15"	Libra	-2.1	00:46	09:50
	28 Feb	15h 23m 00s	-17° 20' 20"	Libra	-2.2	00:19	09:23
SATURN	01 Feb	18h 19m 52s	-22° 28' 44"	Sagittarius	0.6	05:34	13:33
	07 Feb	18h 22m 27s	-22° 31' 41"	Sagittarius	0.6	05:13	13:12
	14 Feb	17h 58m 51s	-22° 30' 51"	Sagittarius	0.4	08:10	16:13
	21 Feb	18h 25m 17s	-22° 25' 57"	Sagittarius	0.6	04:48	12:47
	28 Feb	18h 30m 16s	-22° 22' 38"	Sagittarius	0.6	03:58	11:58

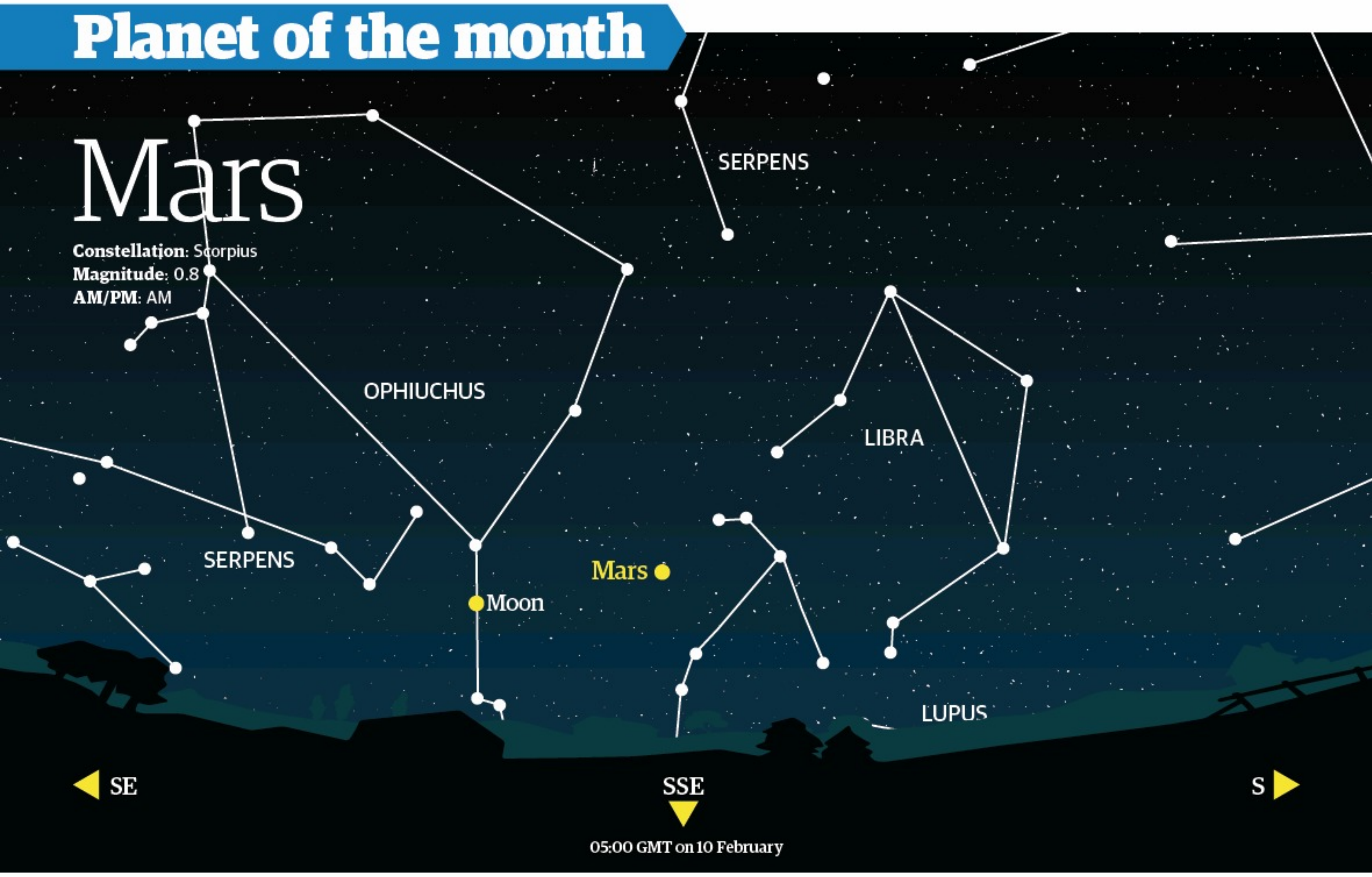
This month's planets

The Red Planet takes pride of place in the morning skies alongside 'rival of Mars' Antares in the constellation of Scorpius

Planet of the month

Mars

Constellation: Scorpius
Magnitude: 0.8
AM/PM: AM



05:00 GMT on 10 February

After spending several miserable months being little more than an extra making up the numbers in the night sky's crowd scenes, Mars is finally starting to take its rightful place as one of the most beautiful and striking objects up there. In summer, when it is at its closest to Earth, it will be a wonderful sight after dark, and we'll be giving you a lot more information about it, and how to see it in all its glory.

As February begins, Mars will be an obvious orange-red star in the morning sky. Rising at around 3am and shining at a very respectable magnitude 1.2, it will be as bright as the summer star Deneb, or the ruddy star Antares, the brightest star in Scorpius - its constellation of residence for the month - which will be very close to it in the morning sky. Antares actually means 'Rival of Mars', so during this month it will be very interesting to compare the colours of Mars and the star it was named in honour of, and see which of the two has the reddest hue to your eyes. On the morning of 10 February Mars and Antares will have the same brightness, both shining at magnitude 1.1, and will also lie just five degrees apart, making them look like a wide 'double star' in the morning sky.

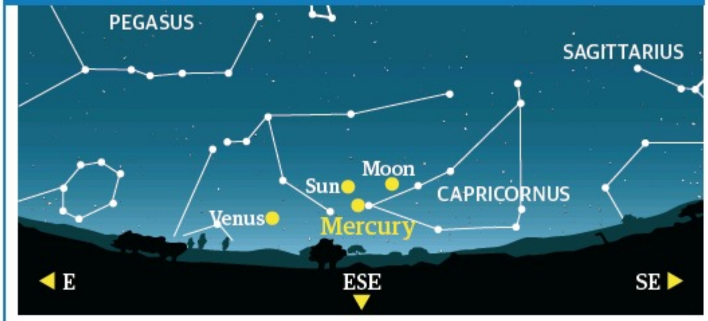
As the month begins, Mars will be easily visible to the naked eye without any help from binoculars or a telescope, but if you can look at it through a telescope you should be able to see light and dark markings on its disc, and maybe even glimpse its bright ice cap too. If you can't see them through your telescope this month, don't worry: you definitely will in summer! During the final days of the month, Mars will start to give a tantalizing hint of just how beautiful it will appear in the summer. It will have brightened considerably and will be shining at magnitude 0.8, almost equal in brightness to the beautiful star Altair.

For the whole of February Mars will be the filling in a pre-dawn planetary sandwich, with fainter Saturn to its lower left and much brighter Jupiter to its upper right. Early in the month it will also be joined in the pre-dawn sky by the waning crescent Moon. On the morning of 8 February the Moon will shine to Mars' upper right. The following morning Mars and the Moon will be just three-and-a-half degrees, or seven Moon widths apart, and with Saturn shining serenely to the pair's lower left and Jupiter blazing to their upper right, they will look very striking. If you have a digital SLR camera that can take time exposures of several seconds you should definitely try to photograph the scene that morning.

STARGAZER

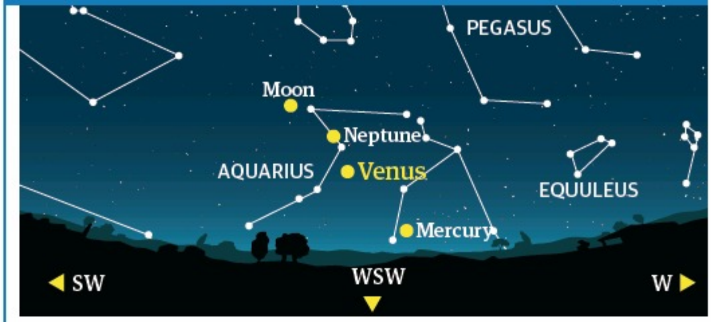
This month's planets

Mercury 08:00 GMT on 15 February



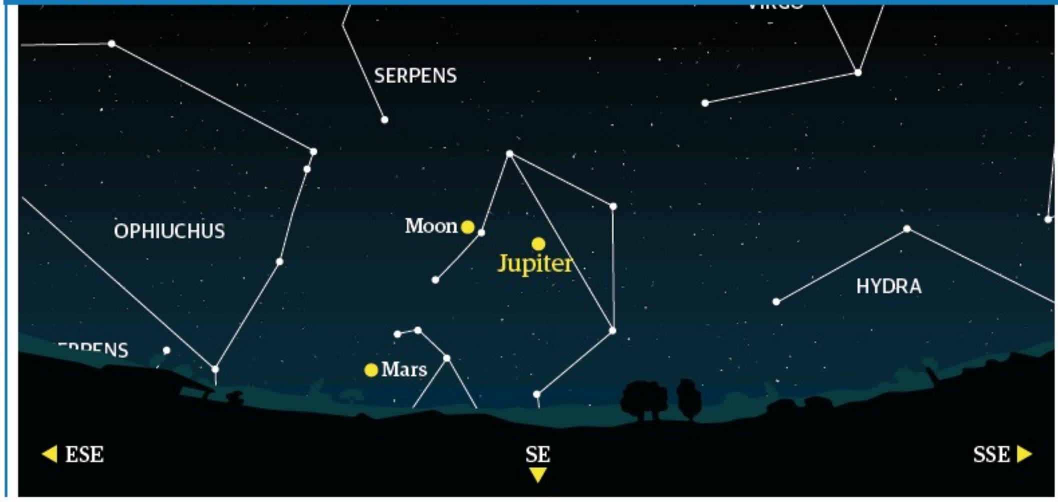
Constellation: Capricorn moving into Aquarius
Magnitude: 0.6, brightening to -1.3
AM/PM: PM
On the very last morning of February, Venus and Mercury will be just two-and-a-half degrees (five Moon widths) apart, looking like a wide double star to the naked eye. By the last day of February, the speedy world will be obvious to the naked eye, shining at a very respectable magnitude -1.3.

Venus 17:00 GMT on 17 February



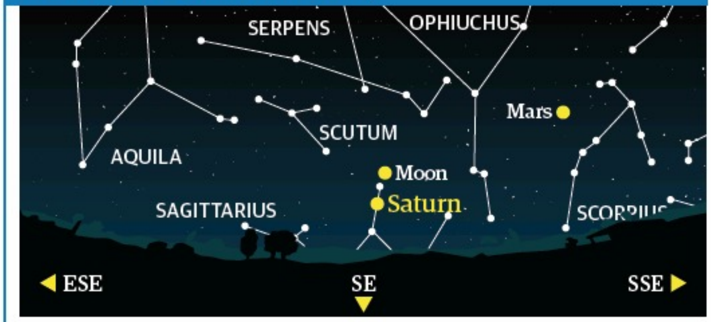
Constellation: Capricorn moving into Aquarius
Magnitude: -3.9
AM/PM: PM
During the latter part of February, Venus will become a very bright 'Evening Star', blazing in the west after dark. Venus will lie to the upper left of fainter Mercury, but look out for a beautiful, blade-thin crescent Moon shining 11 degrees to the upper left of Venus after dark on 17 February.

Jupiter 04:00 GMT on 08 February



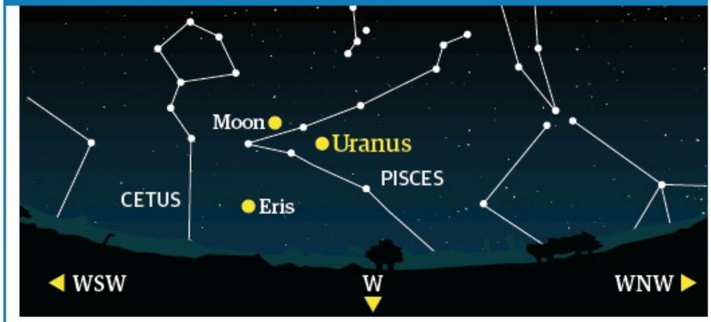
Constellation: Libra
Magnitude: -2.0
AM/PM: AM
February will be a great month for you if you like observing the largest planet in our Solar System – but only if you enjoy getting up early in the morning. Throughout February, Jupiter will be on the end of a long 'chain' of planets, with Mars and Saturn to its lower left. Of the three worlds Jupiter will be by far the brightest, a striking sight to the naked eye. Look out for a beautiful waning crescent Moon passing Jupiter on the mornings of 7 and 8 February. Before dawn on the 8th, the Moon and Jupiter will lie just under five degrees apart, making a very attractive sight in binoculars or a small telescope.

Saturn 05:45 GMT on 11 February

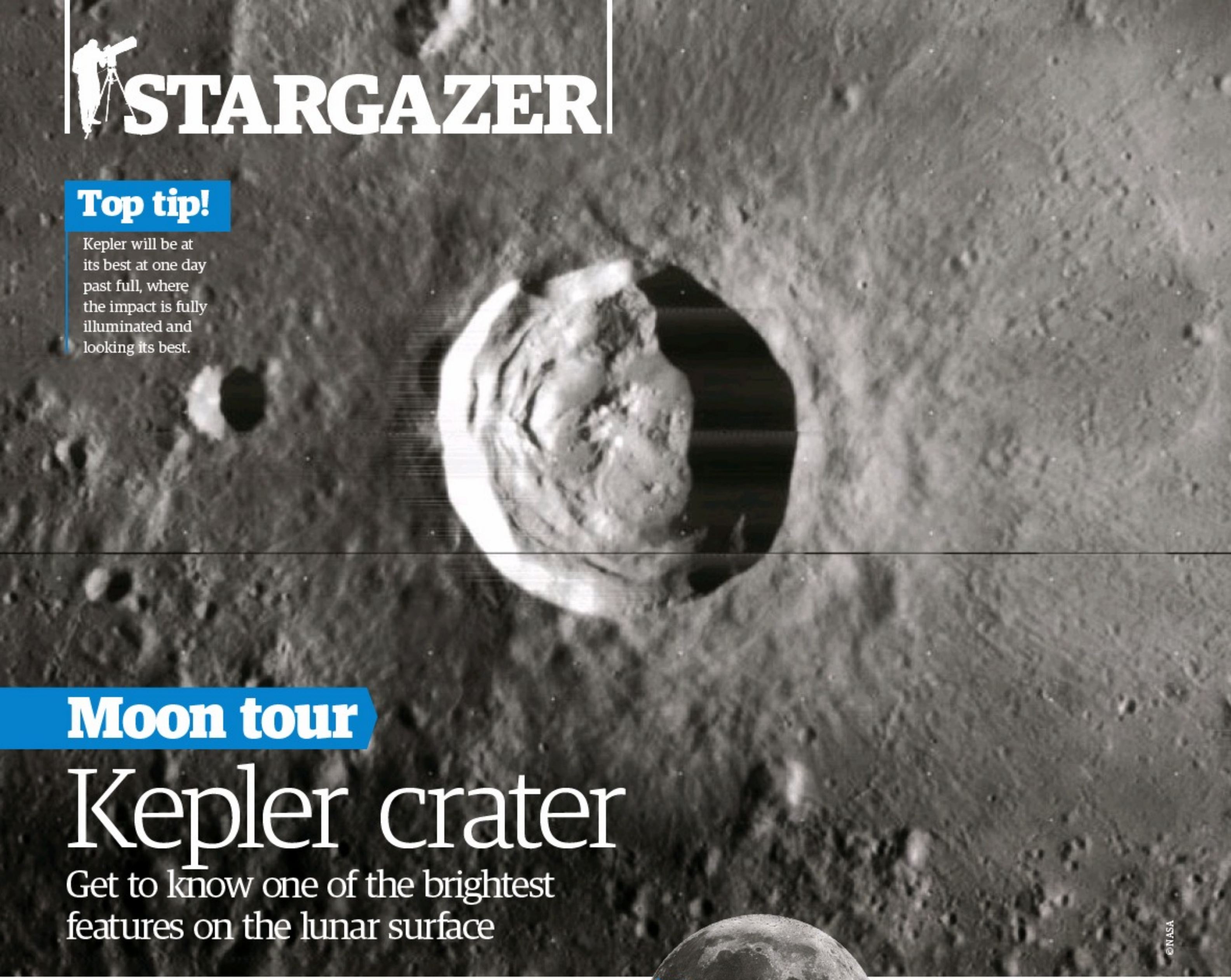


Constellation: Sagittarius
Magnitude: 0.6
AM/PM: AM
Although you'll need a telescope to see the rings, even a modest pair of binoculars will reveal Saturn's largest moon Titan. The waning Moon will appear to drift past Saturn between 11 and 12 February. Only four degrees apart before dawn on the 11th night, Saturn and a thin crescent Moon are certainly worthy of a look.

Uranus 20:45 GMT on 20 February



Constellation: Pisces
Magnitude: 5.8
AM/PM: PM
If you like an observing challenge, then Uranus is the planet for you this month. Its magnitude of 5.8 means it is technically a naked-eye object, but if you need a little help tracking Uranus down, look for it after sunset on the 20 February, when the faraway world will lie just six degrees to the right of a lovely crescent new Moon.



©NASA

Moon tour

Kepler crater

Get to know one of the brightest features on the lunar surface

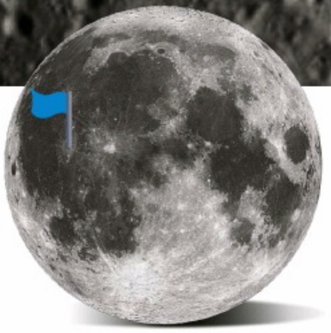
Top tip!

Kepler will be at its best at one day past full, where the impact is fully illuminated and looking its best.

The Moon is a spectacular sight through any telescope - even a small one with low magnification - but not when it's full. Hearing that often surprises people; they think that 'bright equals best' when looking at something through a telescope, but the opposite is true. When the side of the Moon pointing towards the Earth is fully illuminated by sunlight, our planet's natural satellite is so bright it's almost impossible to look at through a telescope eyepiece. If you can manage being dazzled by it for more than a few seconds, all you can see is a flat plate with grey and white patches splattered on it.

If you look at the full Moon through a modest pair of binoculars, or with just the naked eye, you will notice there are four very bright white 'spots' on the Moon with what appear to be bright lines streaking away from them. They look like the holes stones make in ice when thrown onto a frozen-over pond. These bright spots are in fact craters, which are relatively young when compared to the Moon's other impacts and its dark 'seas'. One of these young craters is Kepler, which can be found on the western side of the Moon's face, below and forming a triangle with the equally youthful, but brighter and more obvious craters Copernicus and Aristarchus.

Kepler was formed around 1.1 billion years ago in what is known as the "Copernican Era", when a huge asteroid barrelled in from deep space and slammed into the Moon's surface, blasting a 32-kilometre (20-mile) wide and 2.6-kilometre (1.6-mile) deep hole out of the lava plain of Oceanus Procellarum. Like its near neighbours, Kepler is notable because a huge amount of debris was thrown out of it, which sprayed up into the sky and splashed back down onto the lunar surface, leaving bright streaks and rays painted across it. The longest of Kepler's rays stretches for more than 300 kilometres (186 miles) across the landscape. There are more rays to the west of the crater, which suggests the asteroid which formed it came in from the east at an oblique angle, spraying debris away from the impact site.



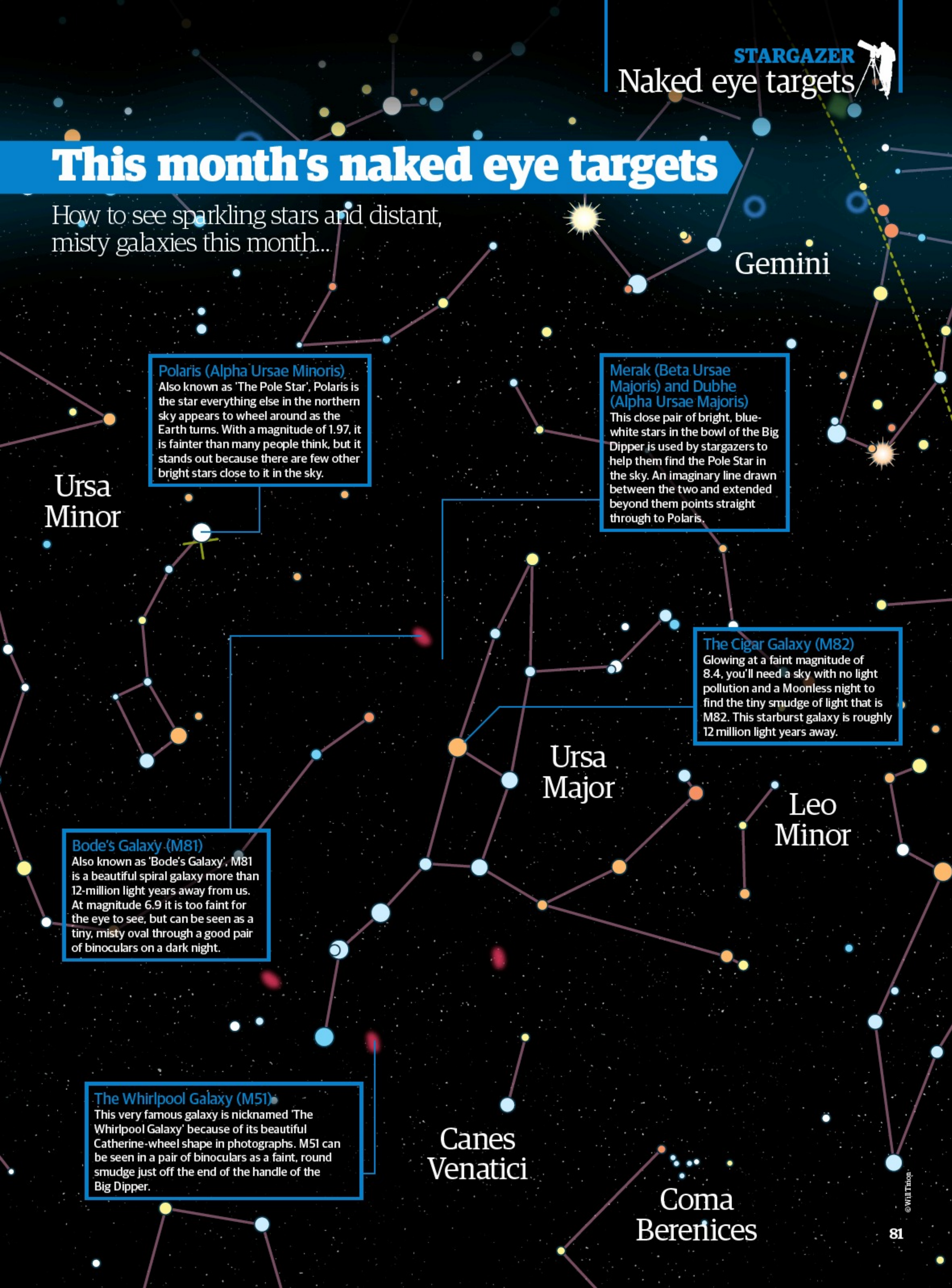
Through a telescope at high magnification, Kepler is revealed to be a fascinating feature. It has a roughly polygonal shape, with outer walls that are sharply defined and smooth-sloped. The inside of the crater is more complicated. Its inner slopes are terraced, leading down to a hummocky, crumpled floor dotted with smaller craters. Its central peak is neither very central or much of a peak, little more than a rough mound of material on the north-west part of the floor. To the north, large landslides have slumped down from the walls, and to the west a crescent-shaped ridge stands out starkly when the Sun's light strikes it at an angle.

Unlike some of the other major lunar features, no spacecraft - crewed or robotic - have yet landed close to Kepler, so its material has not been sampled. However, the crater has been photographed extensively over the years by many satellites and Apollo spacecraft too, so we have very detailed imagery of it to study. In 2013, NASA's Lunar Reconnaissance Orbiter (LRO) flew over Kepler and its spy-satellite-like cameras took breathtakingly high resolution images of debris flows, avalanches of dust and rocks snaking and slithering down its slopes, just like we have seen on Mars. The LRO images clearly show the debris flowed towards, around and even over obstacles in its path.

So, when can you see this fascinating feature? As February begins the Moon is just one day past full, so Kepler is fully illuminated and looking at its best straight away.

This month's naked eye targets

How to see sparkling stars and distant, misty galaxies this month...



Polaris (Alpha Ursae Minoris)
Also known as 'The Pole Star', Polaris is the star everything else in the northern sky appears to wheel around as the Earth turns. With a magnitude of 1.97, it is fainter than many people think, but it stands out because there are few other bright stars close to it in the sky.

Merak (Beta Ursae Majoris) and Dubhe (Alpha Ursae Majoris)
This close pair of bright, blue-white stars in the bowl of the Big Dipper is used by stargazers to help them find the Pole Star in the sky. An imaginary line drawn between the two and extended beyond them points straight through to Polaris.

The Cigar Galaxy (M82)
Glowing at a faint magnitude of 8.4, you'll need a sky with no light pollution and a Moonless night to find the tiny smudge of light that is M82. This starburst galaxy is roughly 12 million light years away.

Bode's Galaxy (M81)
Also known as 'Bode's Galaxy', M81 is a beautiful spiral galaxy more than 12-million light years away from us. At magnitude 6.9 it is too faint for the eye to see, but can be seen as a tiny, misty oval through a good pair of binoculars on a dark night.

The Whirlpool Galaxy (M51)
This very famous galaxy is nicknamed 'The Whirlpool Galaxy' because of its beautiful Catherine-wheel shape in photographs. M51 can be seen in a pair of binoculars as a faint, round smudge just off the end of the handle of the Big Dipper.

©Will Tirion

© Nerush Vladimir

How to...

Watch the Moon block out Aldebaran

Sometimes the lunar limb appears to pass in front of stars and other objects, including planets, in what is known as an occultation. Here's how to watch it happen...

You'll need:

- ✔ Binoculars
- ✔ Telescope
- ✔ Wristwatch
- ✔ Digital camera (optional)

On 23 February, the Moon will occult the bright star Aldebaran in the constellation of Taurus the Bull. Such occultations are fascinating events, but it can depend upon where you are on planet Earth whether you get to see it or not. Even if you don't see it, it is still an interesting thing to observe, as the star will come very close to the Moon.

Although still in daylight for observers in Europe at mid-northern latitudes, the event will be visible if viewed through binoculars or a telescope. Occultations such as this can, of course, occur at any time. As Aldebaran is a bright star, it makes it easier to spot in twilight, or even pre-twilight, skies. The star will appear to wink out as it passes behind the unlit portion of the Moon, which will be in its first quarter phase, and it will reappear suddenly from behind the illuminated side of the Moon around an hour later. The skies will be noticeably darker then, which will make it easier to see. How long the event lasts depends entirely on where you are observing from, as this will govern the ingress and egress points of the star behind the Moon. You may even witness an event known as a 'grazing occultation' if you are located on the right part of Earth. This is when the star appears to skim the edge of the Moon and can seem to wink on and off as it passes behind mountains and other features on the edge of the lunar disc. If you are observing from some parts of Spain, for example, you might see Aldebaran do just this. You will need to check your location carefully on the Internet to find out your likelihood of observing this phenomenon.

> "It can depend upon where you are on planet Earth, whether you get to see it or not"

Apart from being fun to watch, these observations can be of scientific interest too, as long as you have an accurate way to time the event. That aside, you can enjoy the occultation in different ways: just visually, or by recording the event using a still or video camera. Although occultations occur fairly regularly, the ones involving bright stars or planets are considerably less frequent, so make the most of this one.

Tips & tricks

Consider a telescope

You should use a low-power eyepiece with a good field of view for optimum observation.

Be prepared

Set up your telescope in good time to watch this event. This particular occultation occurs during the daylight hours, making it tricky to find Aldebaran.

Timing is everything

It depends on where you are as to when the star will pass behind the Moon and reappear. Knowing your location will help you to work out the exact moment of the occultation.

Make the most of a wristwatch

If you want to record the timing, you will need a watch set to exactly the right time. Use your smartphone if you wish, but stick a red film across the screen to protect your night vision.

Catch the Moon hitting a Bull's eye

They might be a simple spectacle, but occultations are also a rewarding observation

You can use a DSLR or astronomical video camera to record the occultation event. Video is probably more interesting than just shooting stills. You will need a telescope and mount which can track the Moon reasonably accurately for this, at least for the hour or so that the occultation will last. Again, check the Internet for accurate local timings of ingress and egress.

Send your photos to
space@spaceanswers.com

1 Check your local visibility

The website of the British Astronomical Association (BAA) is a good place to visit to check visibility, since it will be able to supply the observing conditions in your area during the event.

2 Set up your equipment in plenty of time

You should make sure everything is working properly in advance, otherwise you run the risk of missing a good view of the occultation.

3 Make use of a wristwatch

Check and make sure your wristwatch or other timing device is set accurately. If it isn't you will end up missing the event entirely, so it's essential that it's set right down to the very second.

4 Look to make a video

Set your video camera running just before the actual occultation to build the tension in your video. Before you film the event, you should run 'filming tests' to make sure everything works.

5 Wait for Aldebaran

Again, set your camera running before the expected reappearance of orange giant star Aldebaran. The star will appear within moments, so ensure you're ready!

6 Send your details to the IOTA

Send your video with timings and location to the International Occultation Timing Association (IOTA). This will also allow others who missed the event the chance to see it.

Messier 35

Deep sky challenge

Tour the twins and a crab

The night skies of February contain some beautiful star clusters and nebulae suitable for all sizes and types of telescope

The constellations of Gemini and Cancer ride reasonably high in the sky at this time of year from mid-northern latitudes, and contain some spectacular star clusters and a very interesting nebula, which is, in fact, a supernova remnant. Gemini borders the Milky Way, so is well positioned to collect some of these lovely objects. It also contains a well-known and lovely double star, alpha Geminorum or 'Castor', easily split in any size of telescope. Cancer, although fairly sparse on the deep-sky objects, does contain two impressive and interesting star clusters worthy of telescope time.

IC 444

1 NGC 2129 (Collinder 77)

This is a small but attractive open star cluster resting on the border of Gemini and Taurus. Through binoculars, the cluster looks like a hazy, white patch, while medium-aperture telescopes will reveal a bright appearance.

2 Messier 35

Messier 35's brightest stars can be resolved using 10x50 binoculars. However, to see the fainter members of this open cluster you'll need a telescope between 6 to 8 inches at low power, truly teasing out a full field.

3 Jellyfish Nebula (IC 443) & IC 444

IC 443, also known as the Jellyfish Nebula for obvious reasons, is best viewed through a telescope with a decent-sized aperture. Not too far away is IC 444, a diffuse feature that will require very good observing conditions to see.

4 NGC 2395

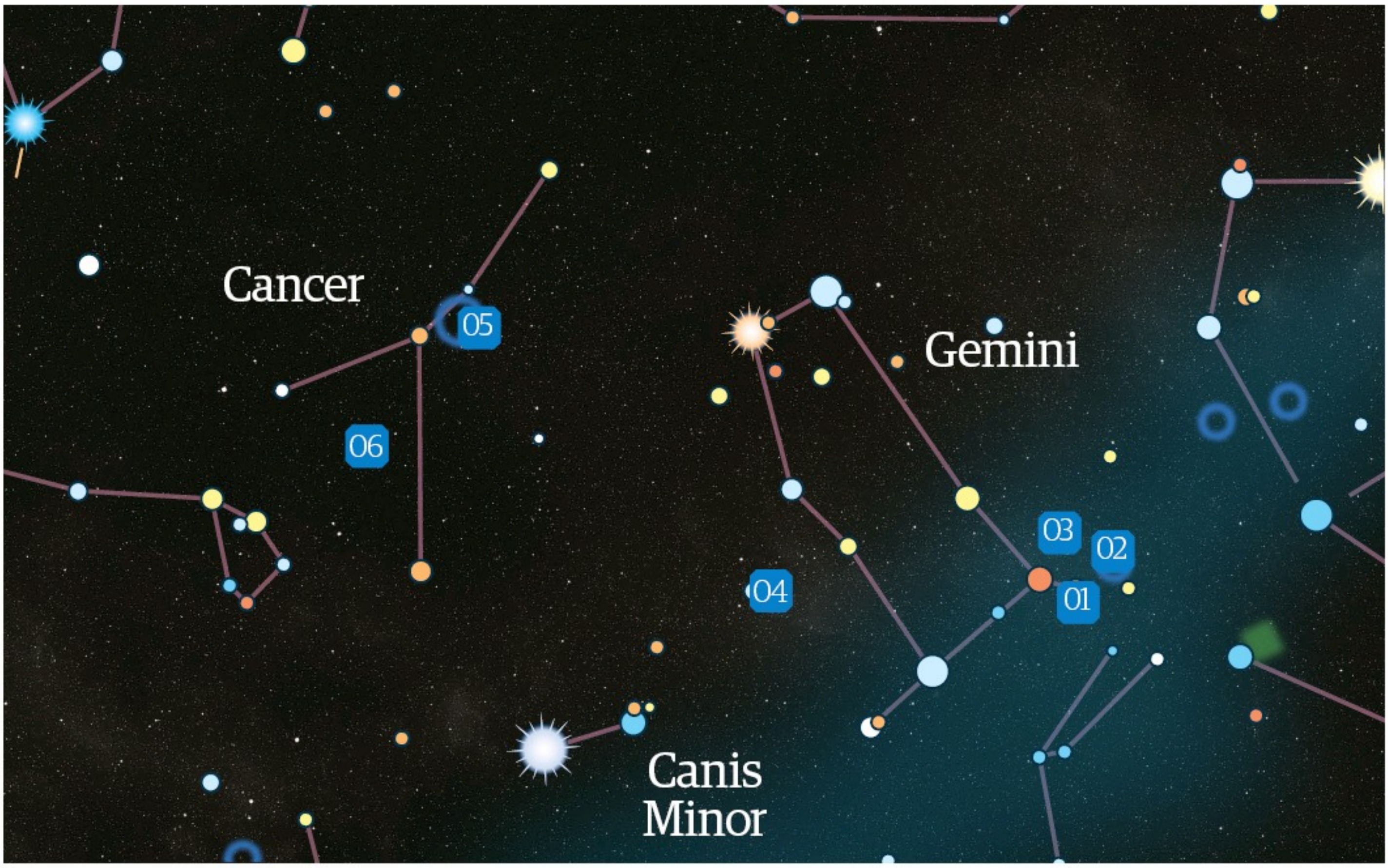
NGC 2395 is a challenging open star cluster, due to its sparsity. Despite its stellar members being spread out, the cluster can be captured in telescopes with smaller apertures, but you will require a medium power.

5 The Beehive Cluster (M44)

A well-known open cluster, the Beehive Cluster, also known as Praesepe (the Manger), is visible using just the unaided eye, thanks to its magnitude of 3.7. A larger telescope will reveal its more than 200 stars in crisper detail.

6 King Cobra Cluster (Messier 67)

Containing stars roughly the same age as our Sun, star cluster Messier 67 has an apparent magnitude of 6.1 and sits between Regulus in Leo and Procyon in Canis Minor. The cluster appears about the same size in the sky as the full Moon.



Beehive Cluster (Messier 44)

© Wil Tirion; NASA; Adam Block/Mount Lemmon SkyCenter/University of Arizona; Miguel Garcia;

How to...

Report a discovery

What do you do if you find something that you think no one has ever seen before in the night sky?

You'll need:

- ✔ Binoculars
- ✔ Telescope
- ✔ Camera
- ✔ Star chart
- ✔ Email access

You have been looking at or imaging a particular part of the night sky and you've noticed something that you haven't spotted before. No doubt you scratch your head and take another look, just to be sure...

More often than not, discoveries are made by using astroimaging, but it is still possible to make a discovery with just the eye and a telescope, or even binoculars. Either way, the process you need to go through to report your finding and have it verified is more or less the same.

You checked the star map and the thing you are seeing does not appear to be on it. You start to get a little excited, but what is this strange interloper and who do you tell? You don't want to appear foolish, so careful checking is most important. There are a number of 'hoops' you will need to jump through if your report is to be taken seriously. You will need to be able to give the exact coordinates of the object, the right ascension and declination, and say whether you believe it to be moving or not. You will need to be able to give a good estimate of the object's brightness and a full description.

It is important to check with various sources of information before you report, and you need to be sure that what you are seeing isn't an imaging artefact, or the result of a nearby bright star creating a 'ghost' image. It is also important to check a good online star map to see if there are any known objects at the coordinates of your discovery. Many such objects turn out to be artificial satellites. It is wise to be a little patient and image or observe the exact same patch of sky the following night or subsequent nights to see if your find is still there.

Depending on the type of object you believe to have discovered, an asteroid for example, you will need to report it to the correct authority. The Central Bureau for Astronomical Telegrams is one such clearing house for objects such as comets and unusual variable stars. You can find the details of specific organisations from the International Astronomical Union, as well as other helpful information about how to report, and what to check before you do.

> "Check with various sources of information before you report"

Tips & tricks

Know your coordinates

You will need to supply exact coordinates of your object, so carefully check this with a star chart or mount.

Work out the magnitude

A good indication of the brightness of your discovery is important, so compare it to other stars.

Check for movement

Check to see if your object is moving over time in relation to the background stars. You will need to watch it through the course of the night in order to get an idea of its movement.

Consider imaging

If you used a camera to image the object, make sure you use the same settings to re-image it.

Check the conditions

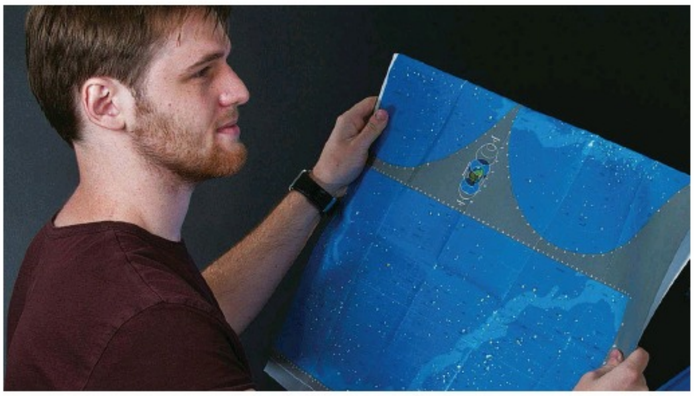
Make a careful note of the atmospheric conditions at the time you discovered the object.

Have you discovered a new astronomical object?

Reporting a find can seem daunting, but it's important to help further our knowledge

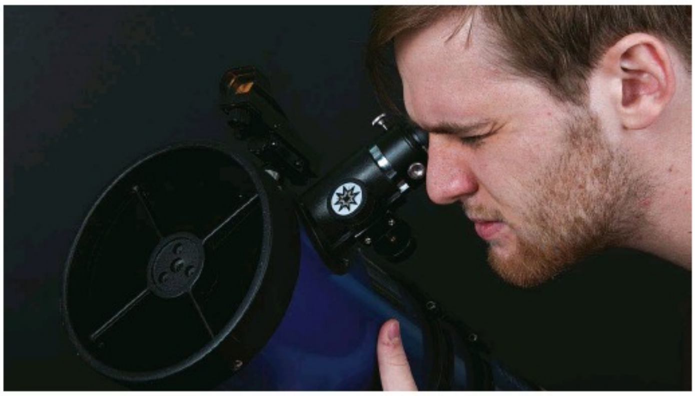
Many discoveries are made by amateur astronomers. These are reported to the professionals to locate and study them in depth, but also to filter out known or misidentified objects. This is why it is important to check as best you can for yourself before you report your find, as it avoids wasting time, and you stand a better chance of being credited with the discovery.

Send your photos to
space@spaceanswers.com



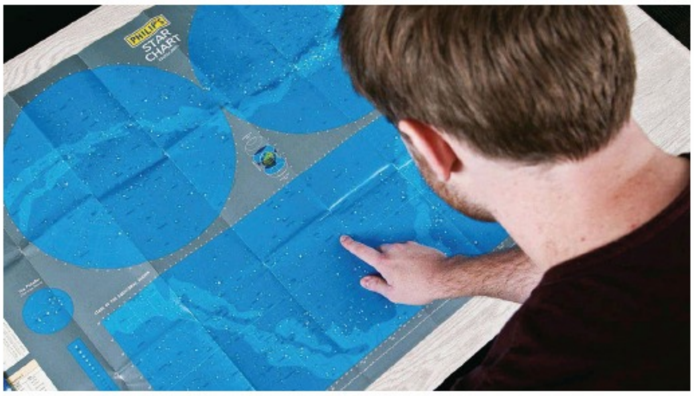
1 Study the sky carefully

Take note of the area of sky you have chosen, or the image you've taken, to see if you have spotted something new. Use a star chart for reference.



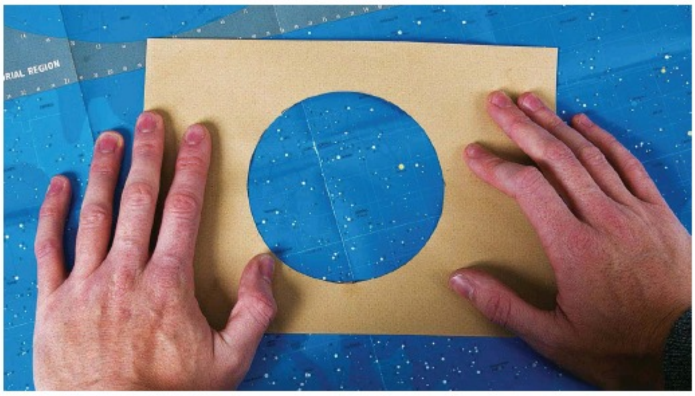
2 Examine your target carefully

Found something unusual? Take a careful look at it with your telescope or binoculars. Undiscovered targets are often faint, so keep this in mind.



3 Make a note of its position

If you're certain you've found a new target, you should consult a star chart for further guidance. Plot its position, making a note of its coordinates.



4 Use other targets as your reference

You should estimate how bright the object is in terms of apparent magnitude. Compare it to other stars or targets in the same field of view.

5 Is it moving?

View or image the object on the next available night - or a few hours later - to see if it has moved. Check for known satellites and asteroids.

6 File your report

Email the correct body (details at **www.iau.org**) concerning the type of object you believe you've found, supplying specific details and an image.

The Northern Hemisphere

If you haven't had the chance to observe some of the colder season's delights, now is the time to catch them

If you enjoy observing some of the large stellar members of our galaxy, then Monoceros (the Unicorn) is the constellation to go to. Orange giants Alpha Monocerotis and Gamma Monocerotis show off their warm hues to owners of binoculars and telescopes and are just an astronomical stone's throw away from open star cluster Messier 50.

Constellations Gemini (the Twins) and Canis Major (the Great Dog) are worthy of observation, too. In Canis Major you'll get to enjoy stunning deep-sky targets Thor's Helmet (NGC 2359), interacting spiral galaxies NGC 2207 and IC 2163 as well as open cluster Messier 41. Head to Gemini to see the Jellyfish Nebula (IC 443), Medusa Nebula and Eskimo Nebula (NGC 2392).

Using the sky chart

This chart is for use at 10pm (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

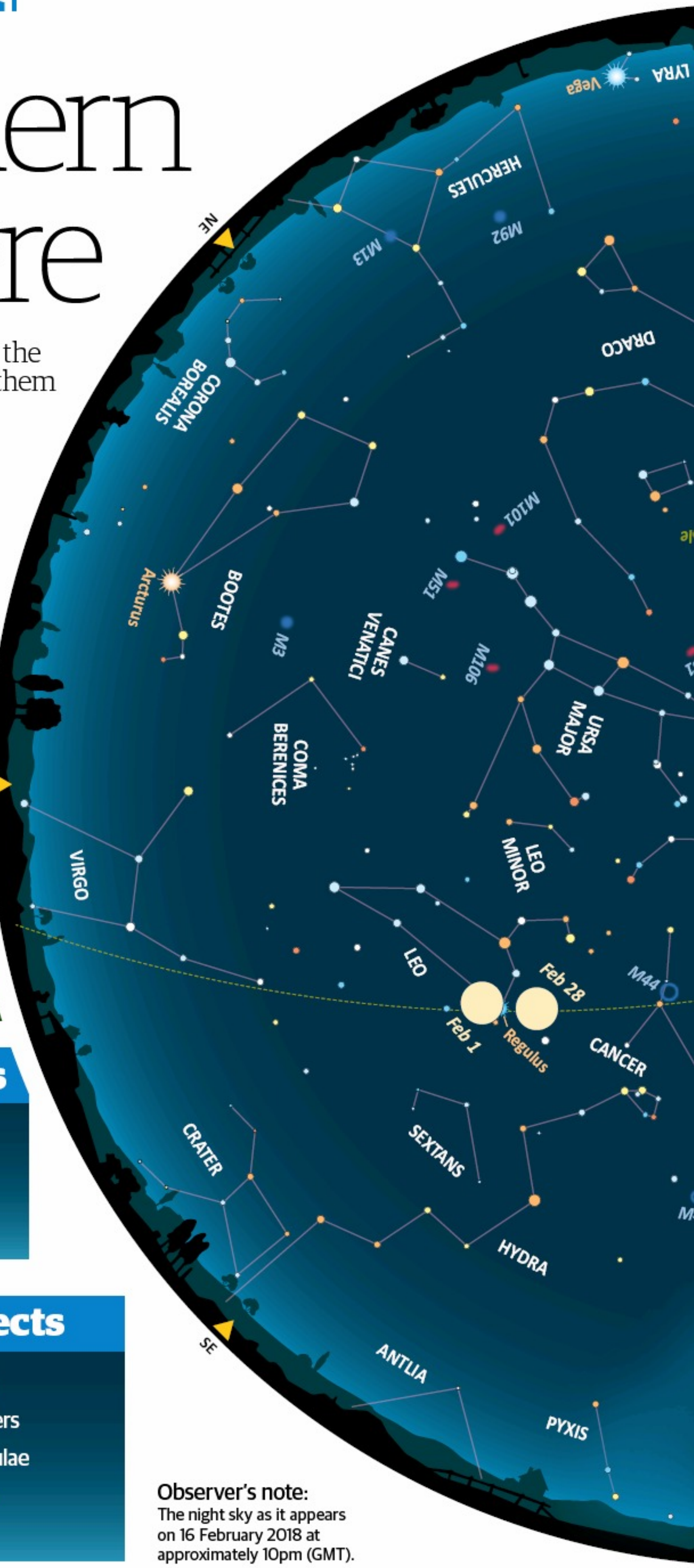
- ✹ Sirius (-1.4)
- ✹ -0.5 to 0.0
- ✹ 0.0 to 0.5
- ✹ 0.5 to 1.0
- ✹ 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

Spectral types

- ✹ ● O-B
- ✹ ● A
- ✹ ● F
- ✹ ● G
- ✹ ● K
- ✹ ● M

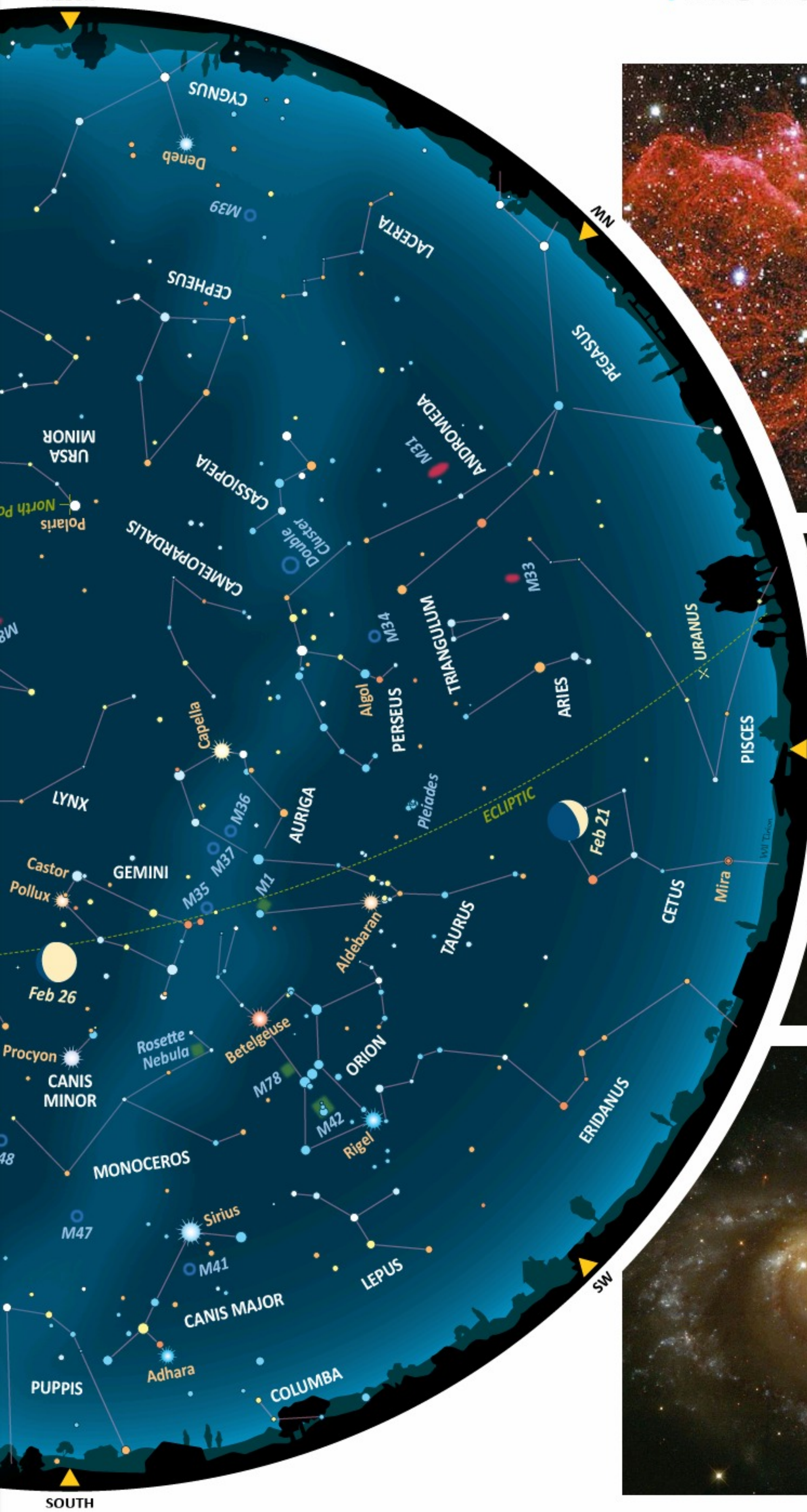
Deep-sky objects

- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies

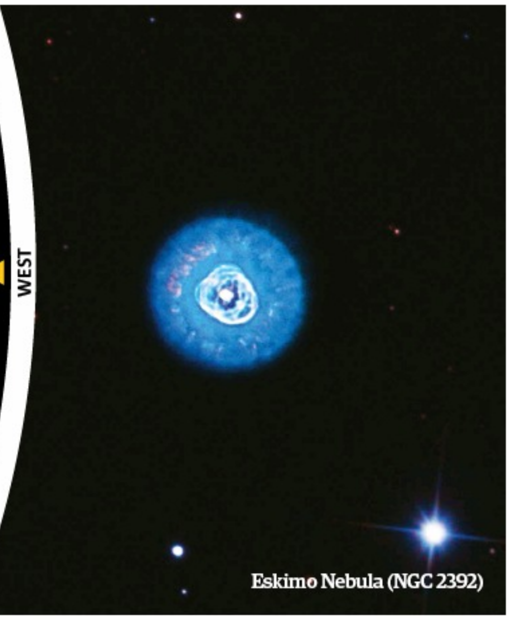


Observer's note:
The night sky as it appears on 16 February 2018 at approximately 10pm (GMT).

The Northern Hemisphere



Jellyfish Nebula (IC 443)

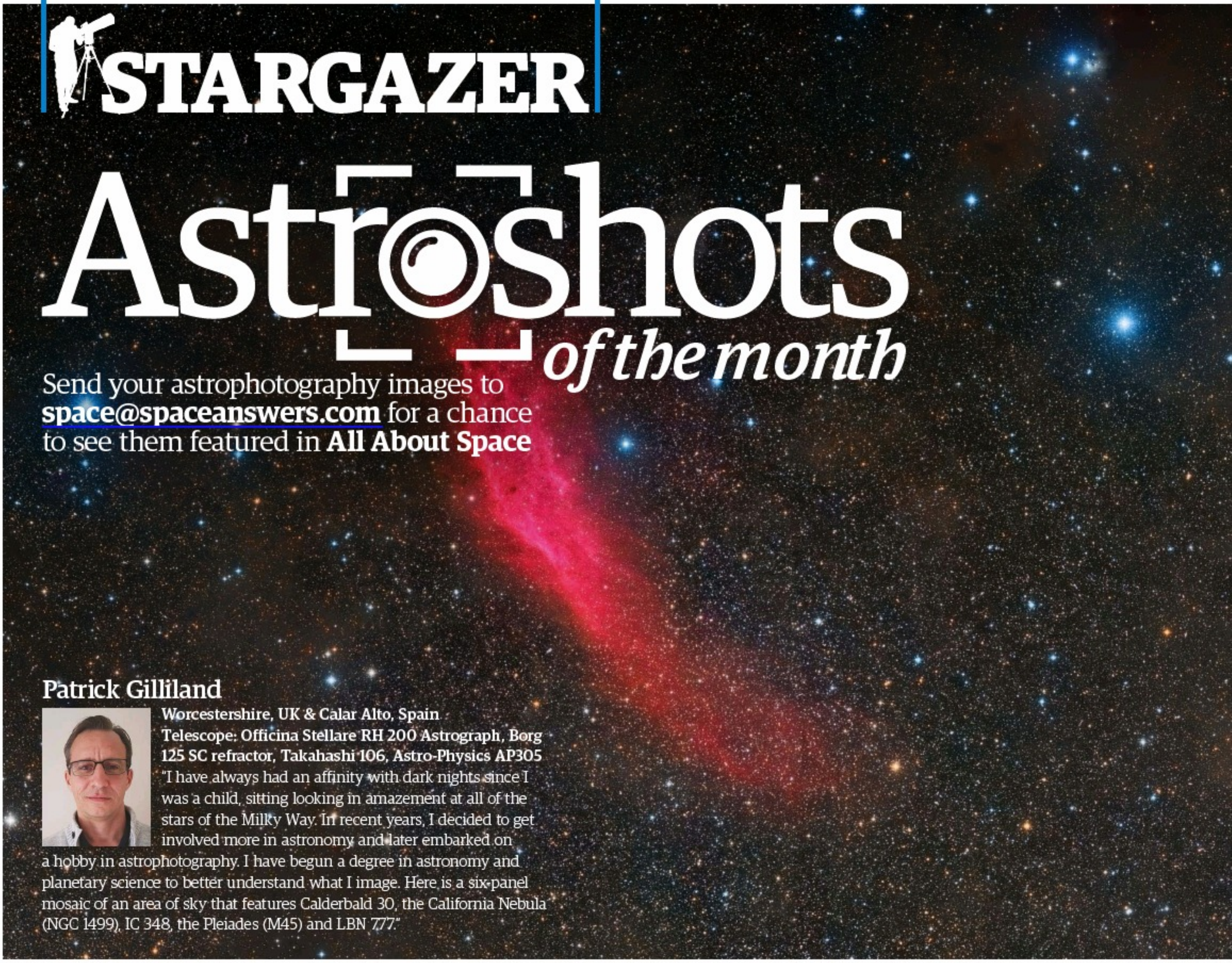

Eskimo Nebula (NGC 2392)

Colliding galaxies,
NGC 2207 and IC 2163

© Wil Tirion; ESA; NASA; Christos Doudoulakis Peterkennett; Jschulman555

Astroshots of the month

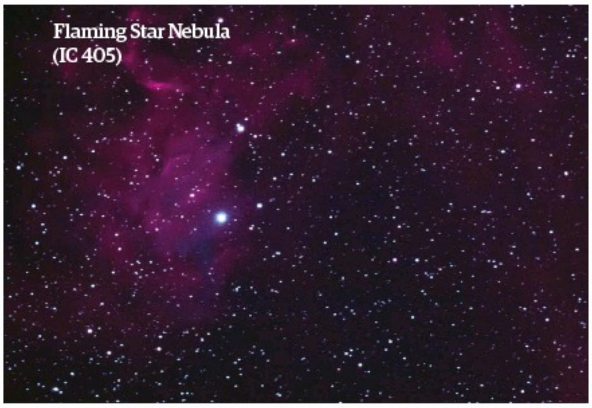
Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



Patrick Gilliland

Worcestershire, UK & Calar Alto, Spain
Telescope: Officina Stellare RH 200 Astrograph, Borg 125 SC refractor, Takahashi 106, Astro-Physics AP305

"I have always had an affinity with dark nights since I was a child, sitting looking in amazement at all of the stars of the Milky Way. In recent years, I decided to get involved more in astronomy and later embarked on a hobby in astrophotography. I have begun a degree in astronomy and planetary science to better understand what I image. Here is a six-panel mosaic of an area of sky that features Calderbald 30, the California Nebula (NGC 1499), IC 348, the Pleiades (M45) and LBN 777."



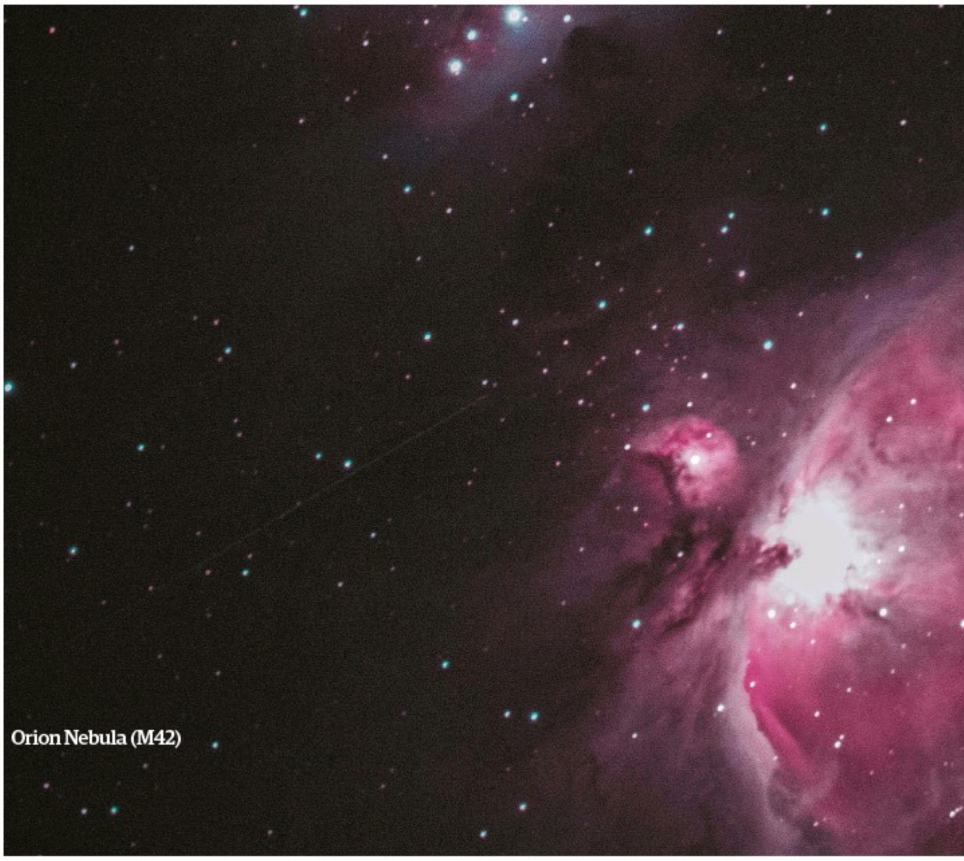
Flaming Star Nebula (IC 405)

James Dean

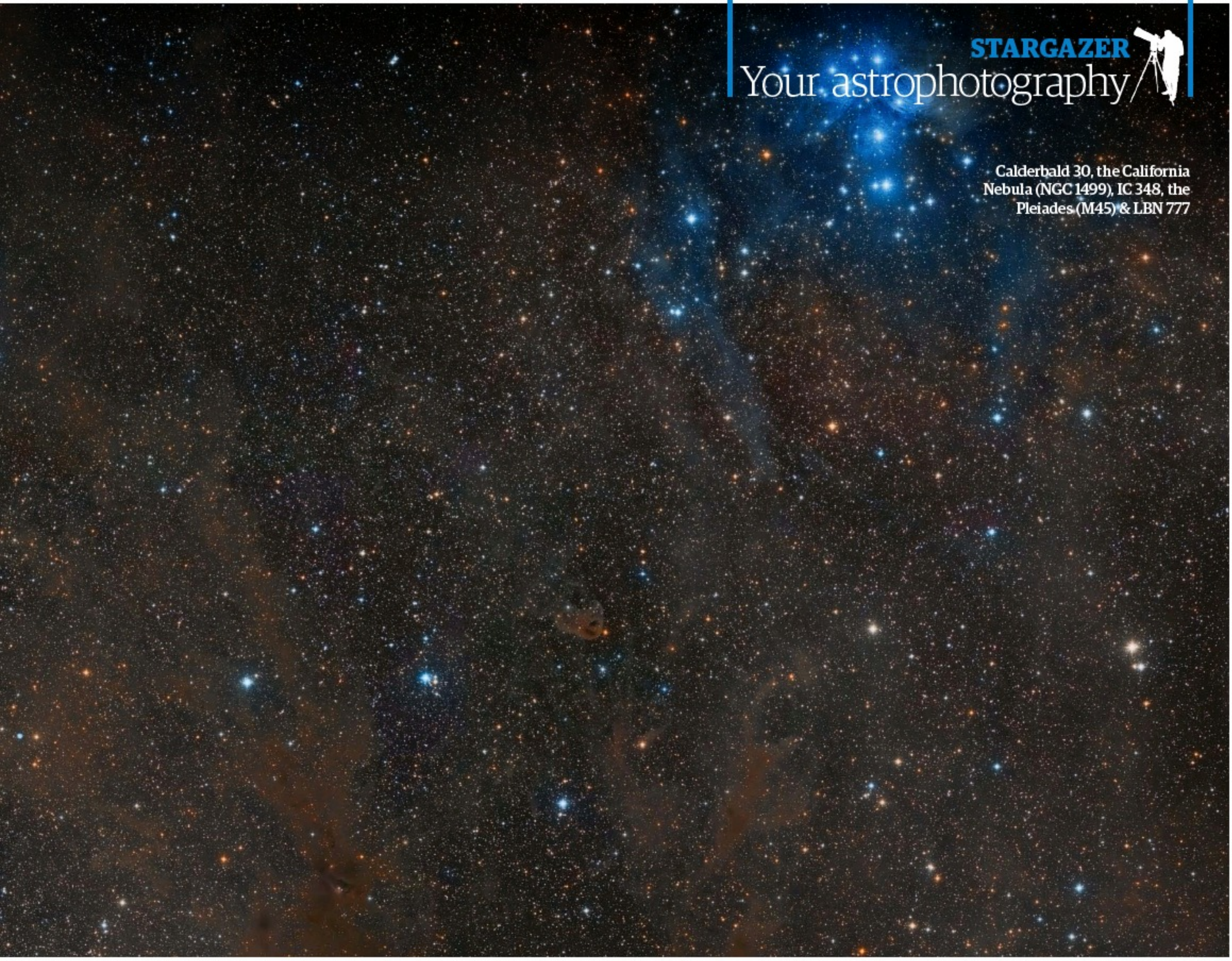
London, UK
Telescope: Takahashi 130

"Using a single exposure of 200 seconds through a modded Canon 600D, I imaged the Flaming Star Nebula (IC 405) in Auriga. This emission/reflection nebula surrounds the bluish star AE Aurigae, which I was able to capture beautifully.

"Using the same equipment, I captured the Orion Nebula (M42), which is visible to the naked eye in the constellation of the Hunter, picking out the Trapezium open cluster at its centre and the gas and dust that surrounds it."



Orion Nebula (M42)



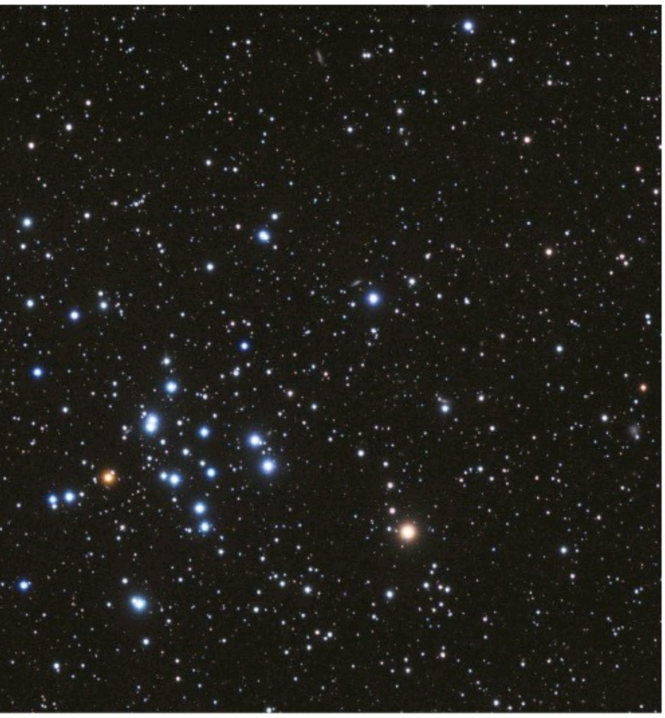
Calderbald 30, the California Nebula (NGC 1499), IC 348, the Pleiades (M45) & LBN 777

Jaspal Chadha

London, UK

Telescope: Takahashi 130

"This pretty, open cluster of stars, Messier 34, is about the size of the full Moon in the night sky. Easy to appreciate in small telescopes, it lies some 1,800-light-years away in the constellation Perseus. At that distance, Messier 34 physically spans about 15 light years. Its stellar members were formed at a similar time, from the same cloud of dust and gas between 200 and 250 million years ago. Like any open star cluster orbiting in the plane of our galaxy, Messier 34 will eventually disperse as it experiences gravitational tides and encounters with the Milky Way's interstellar clouds and other stars. About 5 billion years ago, our own Sun was likely formed in a similar star cluster."



Messier 34

Send your photos to... @spaceanswers @ space@spaceanswers.com

There is the option to produce deep sky images as well as video astronomy

Altair GPCAM2 Colour Camera 290C

An upgrade on a previous edition of this CMOS, this colour camera is capable of taking on the myriad challenges the night sky has to offer

Telescope advice

Cost: £239.99 (approx $299.00)
From: Altair Astro
Type: CMOS
Sensor size: 1/2.8 inch

Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Solar imaging
- Video astronomy
- Auto guiding

Simple, easy and enjoyable; these are just some of the words we could use to describe the Altair GPCAM2 colour camera 290C. It's elegant, lightweight design doesn't give off the impression of a high-tech piece of astrophotography equipment, but what is packed inside this hand-sized camera, that weighs less than some eyepieces, is more than capable of taking on the challenges that the night sky has to offer.

Included in the full package is the Altair GPCAM2 colour camera 290C, a CS-Mount adapter with a built-in UV-IR blocking filter, a 5mm CS to C-mount telescope adapter, a 20mm nosepiece, a USB2.0 connector lead, a 2.1mm wide angle field-of-view meteor lens and a ST-4 guide cable. This equipment is a great starter pack to get an amateur astronomer, just looking at celestial objects through an eyepiece, into a long and illustrious astrophotography hobby. The camera has a 1.25" thread, which is compatible with most telescopes, meaning that all you need to do is take an eyepiece and plug it into the camera. Operating the CMOS is straightforward, as when it is attached to the telescope, it can connect to a computer via the USB lead, before users need to install the appropriate drivers. The instructions for installing the software is clearly detailed in the accompanying manual and only takes a matter of minutes. Unfortunately for our Mac or Linux readers, the drivers are only accessible on Windows. Once installed, the interface is clear, concise and doesn't make for too much hassle.

> "The interface is clear, concise and doesn't make for too much hassle"

From here, the telescope and camera is set up and ready for a night of observations. With such ease in switching between the camera and eyepieces, it makes for an enjoyable night of interchanging views. The camera has proved to be very successful when conducting planetary observations, snapshots of the Moon and checking out sunspots (providing you have a solar filter, which is essential). However, the main challenge when it comes to astrophotography are the deep sky objects, and the SONY Exmor IMX290 colour CMOS sensor is capable of accepting this challenge and yielding impressive results. With a pixel array of 1920x1080 that outputs over 2 million pixels, each with a size of 2.9 microns, this CMOS sensor is equipped with a high sensitivity whilst being able to keep extrinsic noise to a minimum.

When it comes to deep sky objects, much like the Crab Nebula (M1), you need to follow the object as it moves through the night sky, so you don't

The casing of the camera is very sturdy, and its cylindrical design helps improve cooling

cause a smudged image. To do this, it's necessary to have an equatorial mount that's either motorised or at least comes with an attachable motor drive. From this, you can connect the GPCAM2 camera to the equatorial mount drive and use its autoguiding system. This will allow the camera to track an individual star, keeping the object centred in the field of view whilst collecting as many photons as possible resulting in a sharp crisp colour image. This ST-4 port is compatible with most popular mounts, including iOptron, Celestron and Sky-Watcher.

Using the computer operating system, you also have the choice of either an 8-bit or 12-bit system, and you can also change from a 1920x1080 array to a 640x480 and 320x240. This variety of pixel options gives you the choice of focusing on a high pixel count, leading to a high quality image, but at the sacrifice of a slow frames per second (FPS) rate. A high pixel count will come in handy when carrying out exposures of a planet; the best example is Jupiter, as you can gain fine details of its gaseous surface. On the other hand, a shorter frames per second rate will provide you with a much faster response time, which comes in handy when conducting star trails and capturing the paths of meteors racing through the night sky.

In our use of the camera, we are highly impressed by how low the amplitude glow was when conducting long exposures. It was only until we got to the minute mark, with exposure times, did we start to be affected by the amplitude glow. To combat this, it is best to gain multiple short exposures and then combine them using a stacking computer program. A computer program like 'Registax' would come in handy for a job like this, which is an image-processing program that combines images of the same astronomical object to create fine images of your chosen target.

> "The high pixel count comes in handy when carrying out exposures of a planet"

During our review, we decided to try out the camera's capabilities on Jupiter shining at a magnitude of -1.8, a target that was easily recognisable in the clear night sky. As is shone so brightly, it did not require a long exposure time, lasting for a fraction of a second. We turned on the auto-exposure option to let the camera tackle the exposure time, and it returned an image of great quality, with the bands of the gas giant, clearly contrasting in colours and wonderfully crisp. Afterwards we turned our attention to the constellation of Andromeda to hunt down the Andromeda Galaxy (M31), our neighbouring spiral. With several short exposures stacked together, we were able to deduce the central illuminated bulge with dust trails encompassing it. This was a fantastic sight, but the field of view was too small to include the entire galaxy. A mosaic image of the structure could be produced, combining several images of different areas of the galaxy, but this would require further image processing on a program like Adobe Photoshop. From our observing session with the GPCAM2, the images produced are fantastic, while keeping external noise to the very minimum.

This camera is capable to image the Moon, the Sun and plenty of deep sky celestial targets

Our overall impression of Altair Astro's camera is very positive, as it proved to not only meet our expectations, it actually surpassed them. It has the same design as the GPCAM2 224C, which we have previously reviewed at **All About Space**, but its sensor has been upgraded. This makes a huge difference to the quality of the images and gives an excellent value for money when it comes to other compact astronomy cameras.

The operating system for the GPCAM2 is only accessible on Windows

WIN! A MEADE LIGHTBRIDGE MINI 130

Touring the night sky has never been easier with the latest offering from Meade Instruments and Hama UK

WORTH £225

The ultimate grab-and-go telescope, the LightBridge Mini provides the same, high-quality observing experience of its larger truss-tube Dobsonian cousins without compromising portability – just pull it out of the box and you're ready to begin your stargazing experience in seconds.

Boasting an impressive 130mm parabolic aperture with a 650mm focal length, the LightBridge Mini features a simple point-and-look design that makes navigating the sky effortless. Its light-gathering abilities will provide you with superb views of the Moon, planets and a selection of deep-sky objects, such as galaxies and nebulae. The Vixen-style dovetail offers versatility, allowing you to switch mounts, while the parabolic mirror provides images with stunning contrast and clarity.

To be in with a chance of winning, all you have to do is answer this question:

A conjunction occurred on 7 January 2018 between which two planets?

A: Uranus and Neptune

B: Jupiter and Saturn

C: Jupiter and Mars

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All About Space

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The latest books, apps, software, tech and accessories for space and astronomy fans alike

Book Particle Physics Brick by Brick

Cost: £14.99 (approx. $20.33) **From:** Octopus Publishing Group

Particle physics is a tough subject. It's packed of ideas that we can't see, but have been proven. To our current understanding, the Standard Model of particle physics is the best theory we can come up with to explain the smallest scales of matter, and was first stipulated in the 1960s and 1970s. It explains that atoms are made up of the fundamental particles, such as fermions, bosons, leptons and quarks. These are the building blocks for everything - including this magazine - at the tip of your fingers.

With a subject that can be so difficult to understand, there needs to be a relatable, respectable and entertaining medium to explain such phenomena. What better to explain the building blocks of everything than the LEGO® building blocks everyone is so familiar with. When it comes to the content, we were impressed with the knowledge within the book's bindings. It covered all aspects of the history, present thinking and future thinking of the Standard Model. Combined with many well-designed LEGO® illustrations, these ideas become easier to understand and rather enjoyable.

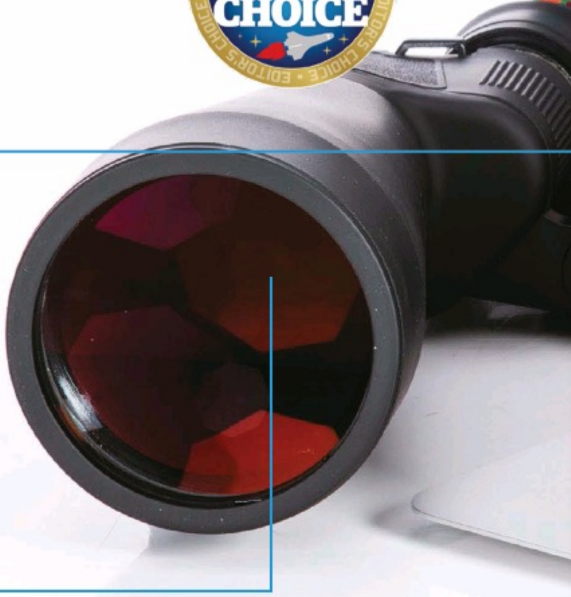
Program Aladin Sky Atlas

Cost: Free **From:** www.aladin.u-strasbg.fr

Most suited to professional astronomers needing an aid in their scientific research, this virtual observatory helps navigate through celestial objects while identifying surrounding neighbours. There are two modes of usage: there is the downloadable 'Desktop' version or the 'Lite' version. Aladin Lite doesn't require an installation process, as it is a simplified version that can be used on any modern browser. On the contrary, Aladin Desktop can be installed on Windows, Linux and Mac, but presents a simple and stale interface.

Don't let the start of this review deter any less advanced astronomers, as not only is this program free, it also holds a vast catalogue of astronomical images from a range of sky surveys that can appreciated by anyone. The images aren't the only impressive aspect of the program, because there is also a fountain of knowledge on the tiniest objects present in the night sky. The information comes from the SIMBAD (Set of Identifications, Measurements, and Bibliography for Astronomical Data) catalogue, as well the VizieR Catalogue Service. This would very much appeal to people who want to further their knowledge and understand the finest details of what is in our enormous universe.

All About Space EDITOR'S CHOICE



Equipment Meade Instruments 15x70 AstroBinoculars

Cost: £100.00 (approx. $135.63) **From:** Hama UK Ltd

We were very impressed with the light-capturing capabilities of the Meade Astro Binoculars 15x70, as they brought some fantastic views into sight. Taking the price into account too, we would consider this a fantastic purchase. The focal length of the binoculars is 70mm, which provides a magnification of 15-times the power of our eyes. This allows deep-sky objects, for example the Andromeda Galaxy (M31) or Pleiades (M45), to be seen at a high quality thanks to its fully multi-coated optics. Also fitted on the binoculars is a centre focus mechanism and rubber eyecups to relieve the pressure on your eyes and make for a more comfortable viewing session.

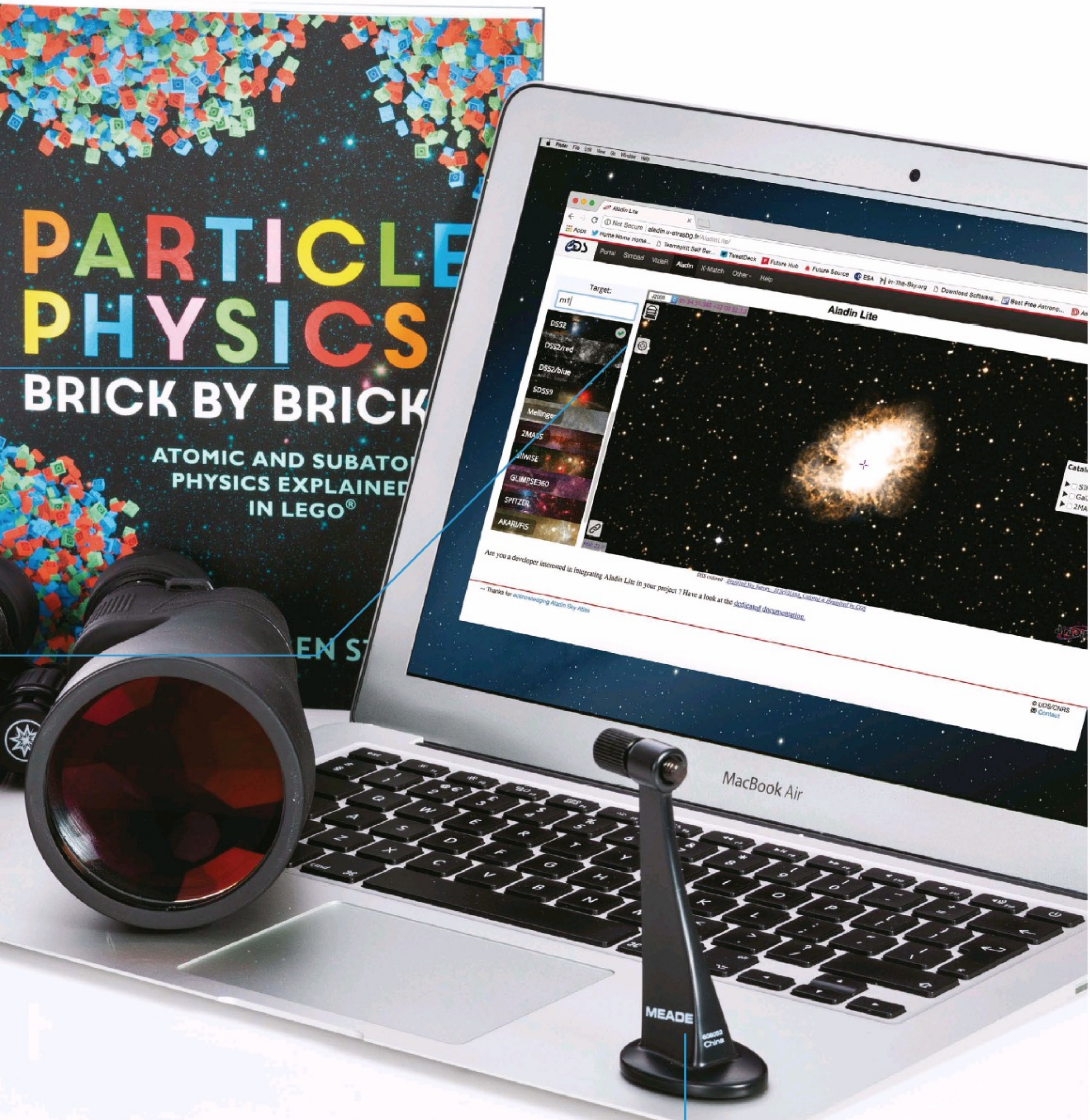
It is surrounded with a rubber grip, but underneath are BaK-4 Porro prism optics. These aren't a heavy pair of binoculars for most people, with the package also including a neck strap. However, it is still capable of being attached to a tripod, allowing for more stable viewings of the Moon, planets, stars and so on. Overall, these binoculars would be best suited for intermediate observations of celestial objects, and will provide long, comfortable viewings.

Accessories Meade Instruments Binocular Tripod Adapter

Cost: £20.00 (approx. $27.13) **From:** Hama UK Ltd

With spring rapidly approaching and the nights getting shorter each day, it would be best to optimise your night-time observing. The beauty of star spotting with binoculars is that they're more lightweight - and much less hassle - than telescopes, and they still open up a wealth of targets. To take advantage of what binoculars have to offer, a tripod would be very useful.

When it comes to Meade Instruments, their binoculars - for example, the 15x70 binoculars reviewed above - will require this sturdy, metal tripod adapter. This adapter will allow you to attach your binoculars to either a Meade Classic 30 Photo Tripod or an Acrobat 80-Advanced Photo Tripod. This causes a problem, as the options of tripod seem very limited. The adapter is also fitted with a rubber pad at the base of the adapter, which helps to make sure the tripod and adapter will not be scratched or damaged when moving across the horizontal. Subsequently after examining the tripod adapter, we were happy with its design and usability. Although there is not much to brag about as it is only a minor piece of equipment, it still meets up to the designated requirements exclusively for Meade equipment.



“What better to explain the building blocks of everything than the LEGO® building blocks”

Mae Jemison

The world-wise astronaut became the very first African-American woman in space

Jemison clocked up 190 hours 30 minutes and 23 seconds in space

© NASA

Being sent into space is all about breaking the bounds of Earth and continuing to strive forward for humanity. Jemison personifies this attitude with her hard work, dedication and intelligence, which led her to being the first African-American woman in space.

Born 17 October 1956, Jemison was born in Decatur, Alabama, but moved to Chicago, Illinois when she was three years old. All things science had captivated Jemison from an early age, including astronomy, biology and chemistry among other topics. This was inspired by her mother and father, who worked as a schoolteacher and carpenter respectively, and eventually led to her gaining a National Achievement Scholarship to Stanford University when she was just 16 years old.

She graduated from Stanford in 1977 after receiving a Bachelor of Science degree in chemical engineering, while also fulfilling the requirements needed for a Bachelor of Arts degree in African and Afro-American studies. This led her to Cornell University, where she gained her Doctorate of Medicine degree in 1981. While obtaining her doctorate, Jemison was able to travel the world and apply her skills in places such as Cuba, Kenya and Thailand.

After completion of her doctorate and a few years as a general practitioner, she joined the Peace Corps, where she served as a medical officer from 1983 to 1985. This demanding experience meant she had to serve in Liberia and Sierra Leone, providing much needed medical support and care.

Upon her return, Jemison took another ambitious step forward in her career and applied for the NASA astronaut program. After Sally Ride became the first American woman in space in 1983, Jemison felt motivated by the idea that the program had become more diversified. Unfortunately, due to the tragic events of the 1986 Space Shuttle Challenger disaster, the selection process was delayed for a year. It wasn't until 1987 when Jemison received the phone call to join the astronaut program, becoming one of 15 candidates from an outstanding 2,000 applicants.

After much training, the dream eventually became a reality. On 12 September 1992, Jemison became the first African-American woman in space when she was launched from the Kennedy Space Center, Florida aboard the Space Shuttle Endeavour. On this mission, more commonly referred to as STS-47, Mae was one of seven crew members that were responsible for conducting important experiments in microgravity. More specifically, she was coinvestigator on two bone cell research experiments, among many other experiments. This rare and truly breathtaking experience ended after just eight days, where Jemison got her tally of time in space up to over 190 hours.

Sadly, this turned out to be her one and only spaceflight, as she closed the curtain on her NASA career in March 1993. She has expressed how she felt confined at NASA, and that she wanted to pursue other important scientific matters. Since then, she has been a professor, she has started up several companies heavily involved in the application of science and technology and she has received multiple honorary doctorates. For now, Jemison resides as the president of the '100 Year Starship' project, which hopes to make human exploration of space beyond the Solar System a reality in the next 100 years.

> "All things science had captivated Jemison from an early age"

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AZ PRONTO ALT-AZIMUTH RANGE

SRP £219
Prod.Code 10272

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SRP £299
Prod.Code 10270

SRP £259
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A classic two-element, air-spaced, multi-coated achromatic refractor. With its long focal length it is ideal for the detailed high-power study of the Moon & planets. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

AZ PRONTO MOUNT & TRIPOD
Prod.Code 20317 **SRP £139**

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SRP £229
AZ5 MOUNT HEAD ONLY
Prod.Code 20312
SRP £159

SRP £299
Prod.Code 10260

EXPLORER-130PS (AZ5)
130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR
With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

SRP £499
Prod.Code 10262

SKYMAX-127 (AZ5)
127mm (5") f/11.8 MAKSUTOV-CASSEGRAIN
The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

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